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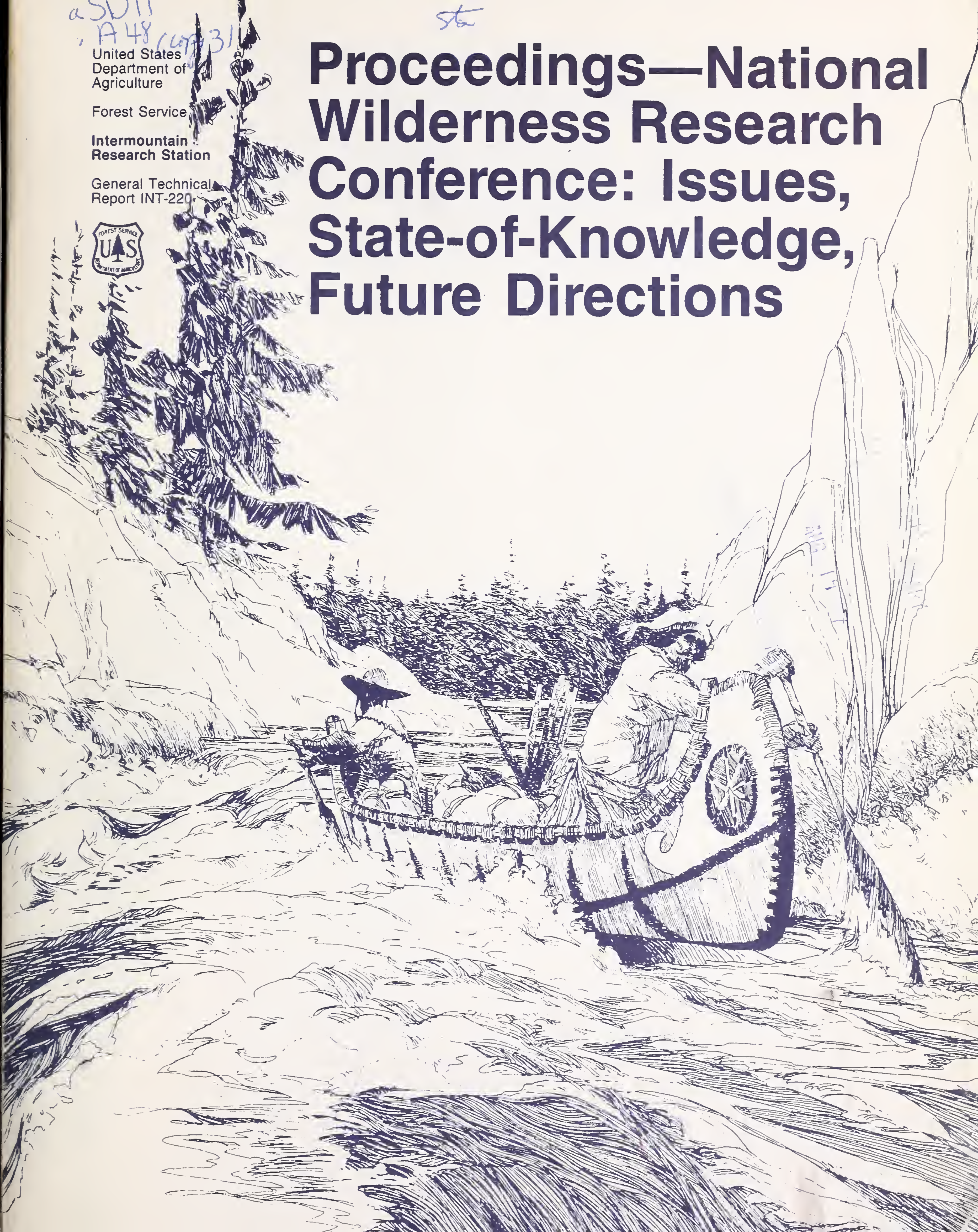

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Intermountain Research Station
324 25th Street
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Proceedings—National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions

Fort Collins, CO, July 23-26, 1985

Compiler:

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- National Park Service

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FOREWORD

The National Wilderness Research Conference drew 400 people to Colorado State University in Fort Collins from July 23 to 26, 1985. The interest displayed by so many participants reflects the important values that wilderness has for Americans 21 years after passage of the Wilderness Act. In that time, the National Wilderness Preservation System has grown from 54 areas totaling 9 million acres to 445 areas and 89 million acres, and spread across the country, with a variety of settings, uses, and problems.

Which lands should be wilderness is still an important issue, but it cannot be the only concern. Protecting and managing the areas classified as wilderness is essential, and the difficulty of this critical task has become more obvious. Management was the focus of the conference, the first ever to concentrate on wilderness research. "Learning to preserve" was the conference theme, highlighting the need for research knowledge to advance our ability to manage wilderness effectively so it will fulfill the goals established in the Wilderness Act.

The long list of conference sponsors reflects the recognition of the importance of wilderness, its management, and needed research. Sponsors were: U.S. Department of the Interior, Bureau of Land Management, Fish and Wildlife Service, and National Park Service; U.S. Department of Agriculture, Forest Service; American Wilderness Alliance; Colorado State University; and Oregon State University. Their support was essential to the conference's success.

Wilderness also involves esthetics and humanistic values that go beyond science, and this side of wilderness was addressed by the 1985 Wilderness Art Exhibit, linked to the conference. Sixty very talented painters and sculptors displayed their works in a 3-day show tied to the research presentations.

Wilderness is a composite of many elements and has numerous uses. Its management is complex and must deal with a wide range of problems. The research conference structure reflected this complexity and breadth.

There are two proceedings volumes. The other volume presents over 70 offered papers reporting current research on nine topics, five dealing with wilderness resource research and four with wilderness user research. This volume includes invited papers that place wilderness values, management problems, and research needs in perspective; papers that review the state-of-research knowledge for the nine topics and provide directions for wilderness research in the future; a section giving a planning-application example; and a conference highlights paper.

We feel that the background perspective papers, including statements from leaders of all four wilderness-managing agencies, will be valuable to wilderness research scientists and managers in the future, as will the discussions of future research priorities. However, we think the nine state-of-knowledge reviews will be invaluable for many years. These are definitive summaries of past research, guides to the literature, evaluations of the coverage and adequacy of research on the topic, and suggestions of critical knowledge gaps.

The papers were written by leading authorities on each topic. They did an outstanding job and should be commended. The many people who thoroughly reviewed these long papers also deserve recognition. Without their efforts, the referee process would have been impossible. Scientists planning research in the future will use these papers as their starting point for wilderness studies of fire, air quality, visitor impacts on soil and vegetation, fish and wildlife, water, recreational use and users, attitudes and behavior, benefits, and visitor management concepts and tools. Managers will also turn to these papers, we hope, to strengthen their programs for management and protection of wilderness. There really is nothing else like these reviews available anywhere. We hope that the Wilderness Research Foundation announced at the conference can contribute to critical research needed to build on the current knowledge described in these nine papers.

The conference was lots of work, lots of fun, and definitely worth it all. I am glad we did it, but it will be quite a while before I am ready to take on the job again! The original idea for the conference came from Glenn E. Haas, College of Forestry and Natural Resources, Colorado State University. Mike J. Manfredo, Department of Resource Recreation, Oregon State University, Sally A. Ranney, President, American Wilderness Alliance, Glenn, and I were the planning committee. Colorado State University and their Office of Conference Services hosted the conference well. The beauty of the setting, with the Front Range of the Rocky Mountains as a backdrop, probably helped inspire the participants as they enthusiastically grappled with wilderness research issues.

Special recognition is deserved by Hollis Williford of Loveland, CO, who drew the cover illustration and generously donated it for use on the two proceedings volumes. The canoeists remind us of the time when most of the continent was wilderness. Hollis is also a Director of the Wilderness Research Foundation, so he is doubly supportive of wilderness research. We thank him greatly.

We hope the major beneficiaries of the conference will be the wilderness resource and the people who will experience it far into the future.

ROBERT C. LUCAS

Proceedings Compiler

CONTENTS

LEARNING TO PRESERVE

Sally A. Ranney

Ladies, gentlemen, and colleagues. I am delighted to be here today, particularly to have the honor of opening this conference and setting the tone for the next 4 days of discussion and presentations. I am most pleased that you are here, and know I speak for the other conference coordinators when I say that we are very much looking forward to your valuable participation in the sessions ahead. The collective experience and information about wildland resources that you represent reflect the finest state-of-the-art knowledge available in the scientific, management, and conservation communities.

As I thought about my charge for today, I could not help but reflect on something someone told me a long time ago. I do not know who first said it, therefore I can't give proper credit. The statement is: "An idea, not coupled with action, will never become greater than the brain cells it occupied."

I submit this to you for consideration on the outside chance it just might be a universal truth. Even if it is not, it is, I believe, an appropriate statement with which to launch a conference dedicated to the advancement of ideas, knowledge, and research about wilderness—and dedicated to that next and most important step of taking research into action—management.

THE WILDERNESS IDEA

Wilderness is one of those omnipotent ideas that grips the mind, heart, body, and spirit which surfaces once or twice in the history of mankind and revolutionizes thinking. In the beginning it was a concept of land ethics, of man-nature relationships, a philosophy, a counterpoint to man's appetite to consume everything nature has to offer. It is the idea that eventually resulted in the masterwork we call the National Wilderness Preservation System.

The concept lingered in the thoughts of Aldo Leopold, Arthur Carhart, and Bob Marshall. With Carhart as a quarterback, Bob Marshall was able to run with the concept (along with the field data he had collected) toward the goal—a system of land areas on this continent that would remain forever wild. He took the idea into the next dimension—the dimension of action. His passion, fire, wisdom, and unwavering commitment along with Leopold's eloquence captured the vision of Howard Zahniser and others. After much struggle and debate, the National Wilderness Preservation System became a reality, a powerful and hopefully enduring statement of the idea.

Yet as the idea flourished, so did the challenges and problems it presented. The question, "How much wilderness is enough?" is still being debated. Some argue that it will never be answered other than subjectively, although I believe history will show we have answered it—and objectively. We need only to look at the statistics and see that we have already, in 200 short years, drawn on approximately 90 percent of our country's land bank principal.

However, because of this subjective debate and the opportunities of our pluralistic system, the movement to protect remaining wildlands within the National Wilderness Preservation System will be carried forward with a deep sense of urgency and patriotic commitment as long as there is 1 acre of wilderness left unprotected and one wilderness advocate still living.

SOUND FOUNDATION NEEDED

Equally as important as the tug-of-war to get areas under the protective umbrella of the Wilderness Act, is the management of these areas—management that has a foundation of sound research and data from which to draw.

If the purpose of the National Wilderness Preservation System is to remain justifiable and those areas under its protection are to truly retain their wilderness values, we must learn to preserve by effectively applying research to management, and we must develop an educated sensitivity about our stewardship responsibilities. These are the critical components for the long-term survival of the wilderness resource.

The challenges, opportunities, and needs presented by our unique, and I might add, internationally envied, Wilderness Preservation System truly belong to the spirit of America. This spirit of resiliency, independence, and ingenuity came from both opportunities and hardships we faced in our contact with the wilderness of this continent when we were an infant nation. And, by protecting the wilderness, we are taking a last stand for that which most precisely symbolizes what America is and hopes to always be.

But if the future of our wildland heritage is to be met successfully, it must be met skillfully, and collectively, by politicians, scientists, managers, educators, industry, conservationists, and the public, all of which are represented at this conference.

FOCUS ON SYNTHESIS

The cornerstone of this effort? The cornerstone is synthesis, and synthesis is the focus of this conference. We are here to share with one another what we have

Opening remarks presented at the National Wilderness Research Conference, Fort Collins, CO; July 23-26, 1985.

learned from wilderness and related studies and to explore management information needs requiring attention.

This opportunity has been made available to you in order to provide a forum where state-of-the-knowledge wilderness research can be presented, where integration and interpretation of what research has found related to wilderness protection and management can be investigated, and where communication can be facilitated.

The result will be the identification of future research needs that are in tandem with management needs, and bonds between people will be initiated or made stronger because it is people, not statistics, that get the job done. Our hope is that out of this conference will come some specific ideas about how ongoing communication networks, which are badly needed among all those represented here, might best take form and be funded.

At the same time we must acknowledge the fact that wilderness holds the answers to questions we still don't even know how to ask. Some might equate this statement with Murphy's Sixth Law of Experimental Procedure: "When working toward the solution to a problem, it is always advisable to have the answer first." Nonetheless it is true. We don't yet know all the answers wilderness may hold. There may well be a point in time when wilderness is the only biological and spiritual reference point from which changes in the rest of the world's environment can be measured.

Consider, if you will, that wilderness could hold more of the future of our planet within its boundaries, within its genetic pools, than we fully recognize or can even understand. If that is true, or even if it is not, the possibility mandates great care and a deeper sense of personal responsibility on our part.

In tangible terms, what is the magnitude and diversity of what we are dealing with? What should our priorities be in contemporary wilderness research and management?

GROWTH AND PROBLEMS

In 21 years, the National Wilderness Preservation System has grown from approximately 9.5 million acres to 89 million acres, a land mass 1.3 times larger than the State of Colorado and larger than a majority of the countries in the world. Some 60 million acres have been identified as still meeting the suitability requirements of the Wilderness Act and could be added to the System. Encompassed are some 455 areas, individually managed by four separate Federal agencies. Areas range in size from 6-acre Pelican Island off the Florida Keys to the 8.7 million-acre Wrangell-St. Elias Mountain Range in Alaska. Every ecosystem except the tall grass prairie is represented.

The Big Slough Wilderness in Texas and many small wilderness areas in the East are directly experiencing the impacts of management practices outside their legal boundaries.

In Florida we are faced with the problems of diversions outside wilderness that are affecting the freshwater drainage within the wilderness. Many wetland wildernesses in the South and Southeast are in a precarious ecological position because of activity that is impacting ocean and shell fish and waterfowl.

Along the Rocky Mountain Front, we are seeing the result of not protecting and managing the range of habitat needed by wilderness-dependent species such as the grizzly bear and bighorn sheep.

Alaska is facing different problems. Under the Alaska National Interest Lands and Conservation Act, the Natives were allowed to select and claim native corporation lands in new refuges, wildernesses, and parks. As a result, they own large inholdings, some as great as 100,000 acres. When these areas are contracted for development, the wilderness values and wildlife are affected, if not seriously threatened. The questions of allowing fly-ins to hunting cabins and the existence of the cabins themselves are subjects of heated controversy.

In desert areas, such as the Organ Pipe Wilderness in Arizona, we have only recently begun to understand the long-term effects of human activity. Deserts, along with the Arctic areas, are the most fragile of all ecosystems. For example, in the California Desert, the cat tracks of General Patton's 1940 tank maneuvers can still be seen.

In the chaparral country there is the question of how to manage fire. The siting of hazardous waste dumps (an item not even on the tip of Bob Marshall's mind), activities that impair air quality within wilderness, and the insidious and not-so-insidious effects of acid rain on pristine watersheds are now demanding attention. And we are still playing cat and mouse with carrying capacity.

Addressing research and management activities and needs both within and outside wilderness boundaries must be a top priority, or ultimately we cannot maintain wilderness. Wildlife, watersheds, and ecosystems do not recognize the artificial boundaries we have placed around our wilderness areas. By not addressing this situation, we are in essence confining our vision, like walking through the dark using a flashlight. Our eyes become accustomed to seeing only what is within the beam of light. Yet we obviously know we will have to deal with many other things out in the dark beyond the flashlight beam.

We need to look beyond the boundaries to construct a vision of how to best manage the wilderness within. We must look beyond the wilderness line on the map and beyond the Congressional Record.

By tackling this challenge, we are seriously testing our general environmental health. Wilderness is where the full circle of environmental integrity is complete. Consequently, we are questioning every environmental standard set to date, many of which we had a hand in establishing, in order to determine if wilderness is being compromised. We must also, in this process, evaluate whether changes are acceptable, and if so, determine the limits of change that can be tolerated.

There is and will continue to be much resistance on this front, and even some brawls, but the questions must be asked if we are to sustain a durable Wilderness System and if policy deficiencies are to be corrected.

As we all are too well aware, wilderness recreation demand and use have exploded. Depending on whose

figures one uses, it has increased anywhere from 200 to 550 percent over the last 30 years. It is interesting that as long ago as 1898 John Muir noted that thousands of "tired, nerve-shaken people were beginning to find out that going to the wilderness . . . was like going home . . . that wilderness was a necessity."

Because recreation has increased so rapidly and has had to be faced head-on with immediate management strategies, the attention of managers and researchers has been drawn consistently in that direction.

BALANCE NEEDED

The balance between anthropocentric and biocentric research has been tipped toward the anthropocentric side of the scales. This has resulted in what I perceive as more subjective management approaches. These focus on how people view wilderness and the variety of the public's demands on wilderness rather than on more objective criteria founded on the facts of the physical and conservation values of the wilderness resource.

It is a difficult balance to maintain because we also recognize that the intangible resources of wilderness are no less important than the material resources. Unless we are willing to say that man's need for what wilderness and parks provide is as fundamental as his material needs, they are lost! The equilibrium must be regained between the two approaches.

Yet, I caution, as did Loren Eisley, that "in the pursuance of a future projected on science, we cannot leave the present to shift for itself." "Intelligent tinkerers," said Aldo Leopold, "save all the parts," and saving all the parts of wilderness is a challenge we must accept. There are many demands on managers, researchers, conservationists, and politicians coming from many directions.

The end result, however, of what we all do must be education. We must educate the public in this country so that each person becomes aware of and understands the wilderness environment and the future it holds. The education process must be done in such a way that the individual is helped toward developing a pattern of ethical and social behavior that reflects this understanding.

Research is critical to us as custodians of our wilderness resources. Research is the cog and management the wheel. Research is the steel hand within the velvet glove of management.

As we explore, exchange, and develop ideas in the next few days, we will become immersed in details and specifics. But let us not forget our broader purpose. What we call conservation, the ultimate of which is embodied in wilderness, is, according to Stewart Udall, "rooted in the needs of man's nature and his inner order of the universe. Conservation puts the future first and experience second."

Ladies and gentlemen, our work IS the future. We are on the leading edge. The next 20 years, indeed over this entire century but particularly in the next 20 years, we will see that what was perceived to be the far-fetched becomes the far-sighted. We are serving the collective challenge we face as trustees of our wildland heritage. We are unraveling the paradox of how to preserve and use wilderness at the same time. We are facing the challenge of defining and defending the rights of the wilderness resource for the sake of the resource itself and all the values it encompasses.

Thank you very much for being here. And welcome!

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Section 1. Perspectives on Wilderness Values, Management, and Research

WILDERNESS VALUES AND CHALLENGES: A COLORADO PERSPECTIVE

David H. Getches

ABSTRACT

Colorado is proud of its 2.6-million-acre wilderness system, which has great value in maintaining air and water quality, providing recreation opportunities, serving as wildlife habitat, and fulfilling human needs for solitude and reflection. American attitudes about wilderness have evolved from fear and hostility to appreciation and attraction. Today, wilderness has great economic importance. Issues include water rights, additional wilderness designation, and release language. Managers face many challenges in properly managing existing wildernesses, and also areas outside designated wilderness. Needs are to proceed with the designation process, manage wildlands in the best manner possible, and resist complacency about the existing wilderness system.

INTRODUCTION

I would like to welcome you to Colorado. It is appropriate that the National Wilderness Research Conference should meet in our State. Colorado attracts nearly 2 million wilderness visitors annually—about one-sixth of all wilderness visitors nationally. Our magnificent wilderness system includes 27 areas with a total of 2.6 million acres. An additional million and a half acres are being considered for wilderness designation.

We are proud of our wilderness lands, spectacular areas with colorful names that reflect our heritage—Eagle's Nest, Indian Peaks, Never Summer, West Elk, Maroon Bells—and candidate areas named Oh-Be-Joyful, Cannibal Plateau, and Sewemup Mesa. These wilderness areas provide us with matchless opportunities for recreation—hiking, hunting, fishing, wildlife viewing, camping and skiing, to name a few. They have incalculable value in helping to keep our watersheds pure, our air clean, and our wildlife insulated from increasing conflicting demands for land. They are living laboratories for research. And, perhaps most important, they are refuges where human needs for solitude and reflection can be satisfied. Even those who do not visit wilderness enjoy psychic benefits from the knowledge that wild areas are there. In short, wilderness areas are a major reason for the special quality of life we enjoy here in Colorado. Similar benefits are enjoyed in the 455 wilderness areas throughout the United States.

Fear and hostility of wilderness by early Americans whose mission it was to tame the wilds have yielded to modern attitudes of respect for our natural heritage. Alexis de Tocqueville observed that "Americans . . . are insensible to the wonders of inanimate nature and they may be said not to perceive the mighty forests that surround them till they fall beneath the hatchet." Americans of the early nineteenth century, according to Tocqueville, would "march across the wilds, draining swamps, turning the course of rivers, peopling solitudes, and subduing nature."

EVOLVING ATTITUDES

After the frontier closed, however, American attitudes evolved into widespread appreciation and attraction for wilderness. Roderick Nash, the noted American wilderness historian, who is with us at this conference, has written that wilderness appreciation is "one of the most remarkable intellectual revolutions in the history of human thought about land."

John Naisbitt, in his popular **Megatrends**, offers an explanation for the increasing tendency of people to seek out primitive forms of recreation. He says that we are experiencing the evolution of a highly personal value system. Perhaps it is an attempt to compensate for the impersonal nature of the technology that increasingly surrounds us. As technology skyrockets, so does the need to balance the spiritual demands of our human nature. As long ago as 1950, George W. Kelley, President of the Colorado Forestry and Horticultural Association, testified before a congressional committee that "wilderness areas have become a spiritual necessity, an antidote to the strains of modern living."

Today there is a broad base of public support for wilderness. Plainly, it has fit into our "national portfolio" as a long-term investment, a trust for future generations. Congress recognized this when it directed management of the public lands for multiple uses, purposes that include wilderness preservation and the attendant nonintensive uses for fish and wildlife habitat and recreation. Accepted public land policy favors permanent retention of lands with such resource values. Even some libertarians concede that government has a role, along with building roads and providing for national defense, in long-range protection of certain natural resources. The American wilderness enterprise has become a source of national pride and an example to other nations. It has succeeded without significant negative economic effects, and has actually proven to be a valuable economic asset for tourism and recreational uses.

Clearly, one of the reasons for the political attractiveness of wilderness has been its economic benefits. Recreation has become an economic mainstay for several western States where fortunes staked on resource development rise and fall with the mercury of industrial prosperity. Recently, tourism has been a safety net for Oregon as it despaired a decline in logging, and for mountain States such as Colorado, Idaho, Wyoming, and Utah as important mining industries and agriculture have been battered by national economics.

In Colorado, recreation and tourism is now the second largest industry, surpassing agriculture and mining. Tourism spending here exceeds $4 billion annually. As a whole, the tourism industry generated 100,000 Colorado jobs last year and produced $503 million in total tax revenues. And tourism is growing. The Colorado Tourism Board tells me that tourism has been at a record rate this year with the trend expected to continue through a bumper summer season.

GROWING IMPORTANCE

The quest for a wilderness experience is becoming increasingly important in meeting recreation demand. Colorado is known for its grand outdoors and vistas, its 54 14,000-foot peaks, its superb fish and wildlife, its blue skies, and its solitude. Many of these treasures are enshrined within wilderness areas. A visitor day to the wilderness in Colorado has been estimated by the Forest Service to have a value of $12.50. This represents the value to the user after the costs of Forest Service management and investment have been paid. Applying this figure to the number of wilderness visitors in 1984, wilderness use generated a net public benefit of $23 million in Colorado. This stands in stark contrast to the over $19 million lost in FY 1982, the most recent year of record, in timber operations in National Forests in Colorado.

The U.S. Forest Service has estimated that 1984 wilderness use in Colorado was directly responsible for generating 2,530 jobs and $71 million in revenues to the economy. It is also significant that 81 percent of existing Colorado wilderness areas and their related economic benefits occur in western Colorado where such benefits are sorely needed. While these economic advantages in no way adequately represent our primary reasons for wilderness protection, they are useful in justifying designation and preservation of the areas in a time of economic stress.

One of the earliest wilderness debates in this country was over the preservation of the Adirondacks. In 1873 advocates of preservation found that their idealistic appeals, based on esthetics, protection of wildlife, and a love of nature, fell on deaf ears. They succeeded only when they appealed to the self-interest of other New Yorkers and the political understanding of the New York legislature. Without sacrificing their idealism, they emphasized New York City's need for a safe, clean, and reliable water supply that the Adirondacks could assure. In response to these arguments, over 700,000 acres were preserved in perpetuity to the benefit of all.

If wilderness opportunities are to remain important in Colorado and throughout the country, more protected areas and innovative management are needed as overuse by enthusiastic crowds threatens to consume fragile wildlands. A 1982 Colorado State University survey done for the American Wilderness Alliance found nearly half of all Colorado residents favored doubling Colorado's wilderness acreage, and 36 percent of the population supported protection of all candidate areas in the State. The study found Coloradans apparently ready to pay for wilderness. The average Colorado family is willing to spend about $19 per year to preserve wilderness, simply to know such areas exist and will be protected into the future.

The results of a more recent poll were announced last week by a group called Volunteers For Outdoor Colorado. The importance of natural resources for recreation was similarly emphasized:

- 97 percent of those polled rated the need to maintain State recreation and natural resources as important;
- 93 percent believe there are strong economic reasons to do so; and
- 86 percent of the people polled said they were willing to do something to help maintain these resources.

Colorado has traditionally been at the forefront of wilderness designation. We were fortunate in avoiding the acrimony and wasteful litigation that plagued many States following the Forest Service's RARE II process. Aggressive bipartisan work by our congressional delegation led to decisive action by Congress on the 1980 Colorado Wilderness Act. That act added 1.4 million acres of Colorado lands to the National Wilderness Preservation System.

A NEW ISSUE

More than 700,000 acres of additional wild areas have been proposed for wilderness designation. Last year a compromise proposal on which members of our congressional delegation had reached consensus on the boundaries of virtually all areas was stopped when a new issue emerged. The issue was whether and to what extent Federal reserved rights may exist in wilderness areas. The United States has never claimed such rights for wilderness areas. But reserved water rights have been claimed on a variety of other public lands—parks, military bases, forests—to help carry out the purposes of reserving the lands. Where they exist, reserved rights cast a cloud of uncertainty over private water uses that commence after the area is set aside for specific Federal purposes. Unquantified reserved rights make it difficult for those with water rights junior to establishment of a Federal reservation to know how valuable or extensive their own rights are. This can frustrate needed investment and development of other resources that depend on water.

Experts differ as to whether there are reserved rights in wilderness, but it would appear that the magnitude of potential effects would be minimal even if water rights could be and were claimed by the United States. To clarify the law and to avoid practical problems, attempts

were made to resolve the water rights issue at the eleventh hour of last year's debate over further designation of Colorado wilderness. Compromise language was being drafted. However, the issue became polarized over a Sierra Club lawsuit seeking to force the Forest Service to claim reserved rights in the wilderness, so polarized that some interests shunned compromise attempts. And that is where we stand—with wilderness designations stalled on the reserved rights question.

In my mind it is essential that we proceed with additional wilderness designation to expand heavily used existing Colorado wilderness areas and to add some new areas in Colorado to the wilderness system. To do so the water rights issue must first be resolved. This is not a problem that rests with the Forest Service, nor is it solely a problem between water interests or wilderness advocates. It is an issue on which we can expect Congress to act only if we ourselves can first work out consensus solution acceptable to the diverse interests that are involved. Until we do, there will be no new wilderness established in Colorado. Furthermore, I fear that unless we resolve the issue soon, it no longer will be just a Colorado issue. Water rights are vital to other western States. The issue could complicate wilderness designation throughout the West. Thus, our solution to the problem must be a solution that will work generically. The wilderness reserved rights issue is a challenge that should be met by Coloradans in the first instance. I believe that language acceptable to all can be found, and I look forward to exploring the possibilities with all interests.

Colorado led the way in solving another national wilderness issue. Last year all wilderness designations were held up over the issue of what type of release language should be included for areas not designated. The approach finally adopted by Senator McClure and Representative Seiberling, which allowed new wilderness designations to proceed, was similar to language forged in the 1980 Colorado Wilderness Act. Thus, the 1980 Colorado approach to release was adopted for other States in 1984. I hope Colorado can similarly break a new trail to compromise over the reserved water rights issue.

OTHER CHALLENGES

There is another set of challenges facing us in managing our existing wilderness areas. Wilderness management is a dynamic process, and the issues and solutions are constantly evolving. Some of the most vexing are control of access by visitors, accommodating important scientific research, reconciling economic needs of those who have property rights within a wilderness, and protecting wilderness from incompatible uses on nearby lands.

Here in Colorado we are overusing several wilderness areas, including Indian Peaks, Maroon Bells-Snowmass, Eagles Nest, Holy Cross, and Big Blue. Wilderness worshippers make pilgrimages to these areas, then literally beat the wildness out of them with their Vibram. In response, the Forest Service has started a permit system to limit the number of campers and to disperse them throughout heavily used areas. At Maroon Bells, summer access is restricted to a shuttle bus system. Land managers are doing their best to fulfill a preservation mission. Yet, can the management regime itself torture wilderness out of existence? If you have to carry a pass in your pocket and camp in a designated site are you in the wilderness? If, as Nash has urged, wilderness is a state of mind, can we destroy it as readily with bureaucracy as with tractors?

Surely it is preferable in the long run to search for better ways to protect wilderness for future generations than it is to give our own generation the opportunity to be the last to enjoy it as wilderness. But if intensive management of designated wilderness drives people to now-pristine backcountry that is not designated as wilderness, those areas may be spoiled even as they await consideration for inclusion in the system.

An issue, recently resolved between the Environmental Protection Agency (EPA) and the Forest Service, involved the use of helicopters to sample western high-altitude lakes to evaluate potential acid deposition impacts. Use of choppers in the wilderness is ordinarily banned because the Wilderness Act of 1964 prohibits the use of motorized equipment. Ironically, carrying out a study in conflict with wilderness regulations could be critical to the future survival of wilderness lakes. As a result, the agencies recently agreed that EPA will take samples outside wilderness using helicopters and the Forest Service will sample wilderness lakes by ground access.

Owners of private, intermingled lands and patented mining claims continue to have access requirements which may conflict with wilderness intent. Conflicts require careful resolution on a case-by-case basis to ensure that legal rights of private parties are respected or compensated in accordance with law, while preventing damage to wilderness values. Unless private rights are observed and people affected by designation are dealt with thoughtfully, those within or affected by potential wilderness areas can be expected to object and to have their voices heard. If they are treated fairly, it will enhance the chances of expanding the wilderness system and establishing public rights.

A wilderness management issue of vital importance is how to manage areas outside designated wilderness. Obviously, the wilderness character of an area does not end abruptly at boundaries set by Congress. There is a continuum of natural features that should be expressed through the management of adjacent lands. Unless extraordinary natural features and habitats are protected, unless development and overuse is controlled near wilderness areas, the wildness of designated areas and their often equally attractive neighboring tracts is threatened. Where the buffer area is publicly owned, agency management and planning should be sensitive to the need to protect a wilderness continuum. Where the buffer area is privately owned, it is incumbent on the agency to work with local governments and property owners to sensitize them as to how wild values can be protected. Acquisition of conservation easements and development rights may be desirable.

MEETING RESPONSIBILITIES

State programs can also help protect unique geologic or biologic features and plant and animal habitat on both public or private lands. For instance, in Colorado we are especially proud of our Natural Areas Program. Since 1977, 47 natural areas containing more than 75,000 acres of land, much of it private, have been successfully designated and protected. Landowner participation is based upon voluntary cooperative agreements between landowners and the State; no areas are designated without landowner permission. The program serves us well in extending the wilderness continuum and increasing our capability to protect important natural features.

The pressures on our wilderness areas can also be met by improving the recreation potential of other lands. Nonwilderness areas in national parks, national forests, State parks, and other Federal and State public lands can relieve that pressure if they are managed and protected to allow dispersed recreation. It seems clear that the hunger for a backcountry experience is not limited to specifically designated wilderness areas. It can be satisfied by properly managed Federal, State, and local recreation areas. But this requires a commitment to manage such lands, at least in part, to sate the thirst of those seeking an outdoors experience that otherwise might have to be quenched by drawing on designated wilderness areas.

An overriding issue at this conference is: How can land managers meet the heady responsibility of protecting our precious wildernesses for future generations? Your mission is frustrated by the meager Federal budgets for wilderness management. We in Colorado are troubled that only 8.5 percent of the National Forest System budget is allocated to recreation. And only about 6 percent of that amount is earmarked for wilderness management. Vital work of the Wilderness Management Research Unit has suffered a 90 percent cut in recent years. Can the challenges of the future in wilderness management be met if wilderness managers are kept in poverty?

In summary, our challenges are many. Said another way, our opportunities are great.

- First, we need to proceed within an increasingly complex wilderness designation process to ensure that additional lands are set aside to remain part of our wild national heritage. If we are to succeed in the West we must pursue new approaches to the question of Federal reserved water rights.

- Second, wildlands will not stay wild without management. We need to manage our wilderness lands in the best manner possible to retain and enhance the essential values that led us to preserve them. At the same time we must allow public access to fragile lands in ways that will not destroy their character. Greater financial resources are needed to allow us to meet high management standards.

- And, finally, we cannot become complacent with the wilderness system that is in place. Wilderness represents only a portion of the natural continuum. As development presses in, we must continue to manage an array of natural lands, recognizing that all public land management decisions have a direct or indirect effect on wilderness.

These are the challenges ahead if wilderness is to have a permanent place in a changing world. Wilderness managers must play in a game dominated by economics and politics, where seemingly crass tradeoffs are regularly made. Aldo Leopold said:

> Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher standard of living is worth its cost in things natural, wild and free.

Today our society has begun **not** to take wild things for granted. Wild things have economic value as well as spiritual value. Wilderness managers can and must participate in the economic and political decision making on economic and political terms. And they can succeed.

I look forward to the ideas and insights of other speakers during this conference as we search together for the means to be better stewards of our wilderness resource.

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CONGRESSIONAL PERSPECTIVES ON THE ORIGIN OF THE WILDERNESS ACT AND ITS MEANING TODAY

Harry Crandell

ABSTRACT

The Country's population growth and movement continue to change political institutions, including Congress. Congress does not initiate actions, but reacts, especially to public issues, and always attempts to achieve consensus. In wilderness legislation and designation, compromise to satisfy various interest groups often stimulates boundary adjustments resulting in less acreage being designated than was originally proposed. Management agencies have misinterpreted the intent of legislation, making it difficult to propose and designate wilderness. For the National Wilderness Preservation System to be maintained, an active, articulate citizenry must speak out in defense of untrammeled wilderness.

INTRODUCTION

As a 1950 graduate of Colorado State University (then, Colorado A & M), I cannot tell you how happy I am to be back on the Aggie campus. The last time I saw this campus was 25 years ago when I was here interviewing students for possible placement with the U.S. Fish and Wildlife Service. Obviously, the University has changed a great deal since then. But that fact should not come as a great surprise, because we live in an era of accelerating change which has had (and is having) tremendous influence on our thinking, lifestyles, and political institutions. As a preamble to a discussion of the U.S. Congress and how it views wilderness, I shall discuss two important factors which have been, and are, major influences of change.

POPULATION MOVEMENT

In 1941, President Franklin Delano Roosevelt stated that there are four essential freedoms:

- Freedom of speech...
- Freedom of religion...
- Freedom from want...
- Freedom from fear...

But Roosevelt did not mention another freedom; a freedom that is a singular American right; a freedom guaranteed by the Constitution; and a freedom taken for granted by us all—freedom of movement.

Americans can move anywhere in the Country they choose, whether it be job related, a family vacation, or simply a trip inspired by a desire to see what is on the other side of the mountain. We do so without fear of retribution and with no legal restrictions. For example, my wife and I drove here from Virginia. We traveled about 2,500 miles through eight States, and not once were we stopped and required to show identification papers or required to request permission to cross a border or subjected to any of the other checks that citizens of most other countries take for granted.

The population shift since World War II is the largest American exodus since the pioneers moved westward to settle the land and tame the wilderness over 100 years ago. And the shift is not to western States alone—Virginia, Georgia, North Carolina, Texas, and others have seen tens of thousands of newcomers take up residence.

POPULATION GROWTH

An allied factor influencing political decision making is that the population has nearly doubled since FDR's speech 45 years ago. This population increase has led to a tripling—some economists estimate a quadrupling—of per capita consumption, leading to the highest standard of living in the World. Thus, the consumptive and nonconsumptive demands on our public lands have increased to a point that would have been unthinkable even a decade ago.

To summarize, the Country's population growth and shifting patterns of that growth have changed—and still are changing—political institutions at all levels of government and have changed the manner in which these institutions deal with issues such as wilderness.

THE CONGRESS

The U.S. Congress is not an inanimate body. It is composed of 535 independent individuals with 535 different points of view. Each member has strengths, weaknesses, and prejudices like anyone else. With the exception of education level (most are lawyers) and a charge to represent their constituencies (which influences their daily decisions), members are a microcosm of the people of the Country as a whole.

In addition, the Congress is not an initiating body and, thus, is not a decision-making institution, nor does it play a leadership role in problem solving. The Congress reacts, seldom initiates, and, more often than not, is very slow to respond to change; be it change in public attitudes (such as civil rights) or economics (such as recession or inflation) or Presidential recommendation (such as cutting Federal expenditures). This is true regardless of party affiliation.

The Congress swings into action once an issue is joined whether it be loud and sustained public outcry where large numbers of their constituents are involved (the recent overriding of the Administration's budget proposed to reduce Social Security benefits is an example) or enacting legislation during times of crisis (such as declaring war).

Even in times of crisis the Congress attempts to achieve agreement among its membership, where "majority rules." In the normal legislative process, the name of the game is "consensus" where agreement is reached through negotiation and "give and take" and the majority agree, while at the same time protecting the rights of the minority.

The Wilderness Act itself reflects most clearly the result of the consensus process. It contains conflicting management direction; for example, agencies must preserve the wilderness character of an area (Sec. 2(b)), while at the same time allowing the continued use of motorboats and aircraft (Sec. 4(d)(1)) and livestock grazing (Sec. 4(d)(4)). This has caused difficulty in developing management policies and, in a few cases, managers have thrown up their hands in despair and let the courts decide "what Congress meant."

It took 8 years for the Wilderness Act to become law. That action did not occur until there was a ground swell of public opinion and Congressional members saw that a vociferous segment of their constituencies, mainly private citizens, was in favor of such a law. On the other hand, a significant number of their constituents, mainly representatives of industry, were opposed to such a law. Conflicting language, intending to make everyone happy, was the inevitable result. But the consensus process did indeed work, and the Wilderness Act is the law of the land.

Wilderness areas are never designated by the sole initiative of the Congress. All units have been incorporated into the National Wilderness Preservation System (NWPS) by action of the Congress only on the recommendation of outside forces. Wilderness units established by the Wilderness Act (and the Wilderness Act itself) were the result of a broad spectrum of citizens pressing Congress to enact the Wilderness bill. Subsequent additions to the NWPS have been in response to the review requirement specified by the Wilderness Act; recommendations by the Forest Service resulting from RARE I and RARE II (in settlement of a court case, incidentally, not a Forest Service initiative); and as a result of local citizens (constituents) bonding together and voicing their opinion to their elected representatives in both the Senate and House.

Even though recommendations have been made, it often takes the authorizing committees of the Congress months or even years to come to grips with the wilderness proposed, partly because of scheduling difficulties, but usually because the hands of a committee (where the legislative action begins) are tied until it has before it a referred bill to consider. Someone has to introduce a bill before a committee can act! Usually, but not always, courtesy requires that a member representing a State or district in that State should be the bill sponsor. Most members are reluctant to stick their necks out and sponsor a bill unless there is an indication of public support for it in advance. Thus, the system has an inertia built into it, based on caution and an acquiescent public. These are the prime reasons that a number of wildlife refuge and National Park wilderness areas, recommended by the President over 10 years ago, are still waiting review by the Congress. Caution and diverse and changing opinions expressed at the grassroots level are the main reasons that most of the RARE II recommendations took several years to enact.

The bulk of the NWPS is located in the public land States, a section of the Country in which most local people have opposed wilderness designations because of fear of change and "lock-up" of resources. While most people in rural communities still oppose wilderness, a majority of urban dwellers do not. A changing attitude (votes) is a direct result of a population shift to the West. Those thousands of people freely moving from States where private land dominates and access is very restricted support wilderness because of opportunities, at last, to enjoy unhindered freedom of movement that the public lands and wilderness furnish. These people not only enjoy the free access that all public lands provide, but they voice their opinion to their elected representatives and, more important, vote!

After a wilderness bill has been introduced and a committee chairman decides to initiate action (usually in the form of public hearings) a significant number of forces are brought into play, not the least of which is a constant debate among the affected politicians as they try to define and redefine the term "wilderness" and its management for their own, sometimes very narrow, purposes. And the argument is not limited to politicians, as the wilderness management agencies, conservationists, industry representatives, and officials from all levels of government testify and lobby, arguing for their own definition or interpretations of wilderness in the form of recommending boundary modifications and management "exceptions" to accommodate diverse needs or uses. Arguments vary dramatically, depending on whether the witness is "for" or "against" wilderness.

We are all products of our own experiences. Even though the Wilderness Act established a new policy direction for public land management, wilderness, like beauty, is in the eye of the beholder. Individual experiences and beliefs have a significant impact on wilderness designations and are not limited to witnesses at hearings, agency personnel, or lobbyists. Members of Congress and staff, usually with little or no knowledge of public land management, impose their own view of wilderness, often with unsatisfactory results. For example, members of Congress will state that a wilderness ought to be "unique" or "beautiful." This belief, usually posed in the form of a question directed at a witness, is rooted in an antiwilderness bias and is intended to set the stage for boundary adjustments or elimination of the area altogether. Of course, neither word is in the Wilderness Act and neither should have a bearing on whether an area is qualified for entry into the NWPS. Too often, however, the high mountain country is a new and thrilling experience to non-Western members and staff (and to recently arrived citizens of a western State as well). Because peaks and rugged terrain are "unique" or "beautiful" to them, their wilderness establishment goal becomes "to save" that part of a wilderness proposal least likely to suffer intrusion. I have in mind here the areas that were included in the Colorado Wilderness Law of 1980 where the bulk of the acreage is above timberline. In order "to save" these "unique" and "beautiful" areas, wilderness proponents fall into the trap carefully set by the antiwilderness forces and agree to boundary adjustments eliminating lands at lower elevations, much more threatened by development than the high country.

Since the legislative process is a consensus process, focusing on boundaries and total acreage, impact on the size of individual wildernesses often is considerable as smaller wilderness units than those originally proposed emerge for the President's signature. Or, if not smaller, with more acreage above timberline than originally proposed, replacing critical watersheds and wildlife habitats at lower elevations.

Why should this be? Why doesn't the Congress just rubberstamp an agency proposal? For example, why hasn't the Congress merely accepted the Forest Service RARE II recommendations? The answer, my friends, is that the overriding legislative goal is to achieve a consensus among competing interests and, thus, among Congressmen themselves. A simplistic description of some of the interest groups would be: The forester believes that trees must be "managed" and the only good tree is one that can be reduced to lumber or pulp; thus, the timber industry lobbies for wilderness boundaries that contain a minimum of trees, crying all the while that lost jobs (meaning votes) are at stake. The western water interests believe that every drop of water should be destined for consumptive use, like watering lawns, and lobbies for minimum boundaries so that future water "development" ideas are not foreclosed. Wildlife managers believe that opportunities for future habitat manipulation, intending to maximize huntable wildlife populations, must not be foreclosed and lobby for assurances that future "management options" will not be forgone. The minerals industry, inferring that the country could be going down the tube because of dependence on foreign mineral sources, lobbies for large exclusions on the speculative grounds that a mother lode of some mineral might be found there somehow, someday. And the wilderness users, particularly the newer recruits to a State, believe that a wilderness area is a recreation area alone and their exclusive province and lobby "to save" the most spectacular, mosquito-free part of a wilderness proposal (meaning high-altitude peaks). Even the Forest Service lobbies for and against changes in its own wilderness proposal, which usually was the minimum to begin with.

The consensus process throws all of these competing forces into the legislative pot, stirs mightily, and adds ingredients represented by the off-road vehicle interests, stockmen, highway departments, local politicians, hunters, and anglers. Add those who prefer to drive their pickup to the site (translation: access) and the emerging wilderness is a much different stew than when the process began some months, or even years, earlier. The spice ingredient of the stew is the fact that members very seldom "roll over" the representative of the district in which the wilderness is located. So there is usually more give than take during the process unless the representative is a strong wilderness advocate, which is seldom.

WILDERNESS MANAGEMENT

For many years there was little direction by the Congress relative to managing an area once it was placed in the NWPS by law. The Wilderness Act, of course, is flexible in nature regarding qualification standards for entry into the NWPS, but more stringent regarding management afterward, except for certain "special provisions" in the law, the applicability of which is not universal.

The initial review standards established by the Wilderness Act required the U.S. Forest Service to review and make recommendations, within 10 years, concerning wilderness suitability or nonsuitability of already established primitive areas. The law did not bar review of other National Forest lands, so RARE I and RARE II were not in conflict with the intent of the Wilderness Act even though the Forest Service was forced to review roadless lands adjacent to primitive areas and roadless lands in general because of court decisions on lawsuits filed by conservation organizations. The National Park Service and U.S. Fish and Wildlife Service were required to review all roadless areas of 5,000 acres or more. The Fish and Wildlife Service also was directed to review all roadless islands.

The Forest Service review mandate required little interpretation because the areas were already established administratively (except for enlargements to or a deletion from a primitive area which were under consideration), but considerable debate occurred in the Interior Department as it wrestled with defining "roadless area," "roadless islands," and "wilderness." The Department finally applied the definition in Sec. 2(c) of the Wilderness Act to the latter. While the Forest Service promptly moved forward with its review of primitive areas, the Interior Department, displaying a deep antiwilderness bias, took over 2 years to issue draft regulations, which were required before the review process could proceed. Even so, all three of the wilderness agencies confused the entry standard of Sec. 2(c) with wilderness management provisions of Sec. 4 and are continuing to do so to this day. The latest arrival on the wilderness review and management scene, the Bureau of Land Management, has fallen into the same trap. Considerable delay in conducting reviews, controversy over proposed boundaries, and citizen lawsuits have resulted, mainly because of a tendency to misinterpret these criteria in a most restrictive manner.

The Forest Service, for example, insisted for years that there should be no noticeable works of man in or near a potential wilderness area. And the Agency persisted in this purity point of view even though the Congress, responding to citizen concerns throughout the Country, enacted the so-called Eastern National Forest Wilderness Law of 1974, trying to restate the notion that public land areas which had "felt the hand of man" could indeed be classified as wilderness if left alone to regenerate. The Forest Service persisted in the West, however, applying such strict standards of purity that virtually no roadless area would qualify as wilderness. Again, the Congress stepped in, again at the urging of conservationists nationwide, and enacted a law. The Endangered American Wilderness Act of 1978 struck down the belief that the works of man need not be entirely unnoticeable within or adjacent to a roadless area, but merely be "substantially unnoticeable" as stated in the Wilderness Act. That law also addressed certain uses that the Forest Service felt were not compatible with wilderness. Why should it be necessary for the Congress to get involved at all in these questions? Shouldn't the guidance provided by the Wilderness Act be sufficient? Obviously not.

Yet, the problem is not with the Wilderness Act itself. The problem is in the minds of people charged with the responsibility of either making the initial identification of a potential wilderness area for review, or in developing management programs afterward. The Wilderness Act is flexible enough to accommodate a wide range of opinions, ideas, and interpretations. Policies are nothing more than ideas put on paper and distributed throughout agencies for management guidance. As such, they are subject to change.

Again, we all are products of our individual experiences, and the perceptions and experiences or lack thereof of people in positions of authority dominate policy formulation, which, in turn, causes these misinterpretations of the law to become national policy. For example, the word "untrammeled" was carefully selected by Howard Zahniser, drafter of the wilderness law, to reflect a wilderness condition of being "left to operate freely." But, untrammeled has been misinterpreted by Forest Service wilderness review teams to mean "untrampled." When coupled with an interpretation of "substantially unnoticeable" to mean "unnoticeable," this has caused thousands of acres of roadless lands to be summarily dismissed from further consideration as wilderness. The Congress, responding to appeals by conservationists, has consistently overruled these misinterpretations of the law and has placed lands in the NWPS that the Forest Service had previously rejected. While "untrammeled" is an entry guide, it is frequently utilized as a management guide as well, which has led to all sorts of problems when defined as "untrampled."

The overriding management direction of the Wilderness Act is found in Sec. 4(b), which directs agencies "to preserve the wilderness character" of wilderness units under their administration. Yet, to my knowledge, none of the wilderness management agencies has ever tried to document the exact combination of ingredients composing the wilderness character of individual wilderness units in order to develop management standards intending to preserve the wilderness character of each unit. And that lack of documentation is the crux of the wilderness management argument and is the reason why there is an increasing number of symposia and conferences in which "wilderness management" is the focal point.

In summary, agency management policies are developed on a national scale, applying equally to all wilderness units, regardless of ecological condition or location. Yet, wilderness areas are like fingerprints, each differing from any other, even though some are located in close proximity. Management policies must be developed on an individual unit basis, within a broad national policy framework. The present method of attempting to develop detailed policies applicable to all wilderness units equally simply has not worked and should be shelved until the wilderness character of each and every wilderness area has been researched, documented, reviewed by the public, and approved.

THE FUTURE

What does the future hold for the National Wilderness Preservation System and its management? While nobody can predict the future with finite accuracy, there are trends present today that might provide a clue.

1. *Population Growth.*—Despite a relatively low birthrate, the Country's population will continue to grow, placing greater and greater demands on natural resource utilization. Thus, the setting aside of areas of the public lands as wilderness will become increasingly difficult unless a larger percentage of the public develops awareness of the value of the preservation of natural places for the future. The point here is that without a continual growth in the numbers of people speaking out for wilderness designations, it is unlikely that the Congress will be very anxious to designate very many of them.

2. *Population Shifts.*—Demographers are predicting that the relatively recent population shift to the West and Southwest will decline in terms of percentage of the population as a whole because of the lack of jobs, primarily. Another constraint, as time passes, might be the lack of water in some States to maintain the "quality of life" that most people have come to expect. This means that there could be fewer local people (percentagewise) interested in preserving new wildernesses or protecting and defending local units of the NWPS from intrusion.

3. *Freedom of Movement.*—While the freedom to move about the Country at will won't change, freedom to move about the public lands, especially wilderness areas, will be restricted, as it should. Human impacts on some wilderness areas (such as Indian Peaks south of Fort Collins) are already so severe that they would not qualify today for entry into the NWPS because primeval character and influence, solitude, and a natural condition have been sacrificed. Further, the Forest Service doubtless is in violation of the intent, if not the spirit, of the Wilderness Act because these heavily impacted units simply are not being left unimpaired nor is their wilderness character being preserved. Certainly, none of them is "untrammeled," but, rather, they are being "trampled" to death by a well-meaning, but chest-thumping, freedom-of-movement endowed, public.

Why are some wilderness areas being loved to death? Close proximity to huge urban centers, ease of access, and size are important factors, of course. But the primary reason that the purposes of the Wilderness Act are being subverted is the dramatic change in public attitudes toward wilderness in the past 10 to 15 years. The bulk of the public now views wildernesses as being primarily (and perhaps solely) recreation areas, open to all who have the means to get to them. This significant change is the fault of no single institution, but is the sum of a combination of changing organizational and individual attitudes toward wilderness.

The founders of the wilderness movement had an ideal in mind, conditioned by their own individual experiences. For example, Robert Marshall, a hiker, viewed wilderness from a lonesome, solitary, seeking-solitude point of view; Aldo Leopold viewed wilderness as a natural, wildlife habitat preservation area where man hunted, fished, and viewed wildlife on natures's terms; Harvey Broome viewed wilderness as a means of restoring and preserving the natural scene with the Great Smoky Mountains as his example; Benton McKaye, a land-use planner, envisioned wilderness as a place for urban dwellers to seek renewal,

alone, in a natural setting; and so on. None, of course, in the 1930's could predict the subsequent tremendous population growth, the huge exodus of people to other locations in the Country, the 40-hour (and less) work week and the resulting increase in leisure time available to the so-called working man; and none could predict the exponential growth in outdoor types of activities. Nevertheless, the Wilderness Act is clear that recreation is one (among five) of the public purposes to which wilderness areas are devoted (recreation is an equal, not a primary, purpose), all of which are conditioned by the Sec. 4(b) directive "to preserve the wilderness character of the area." The wilderness management agencies, especially the Forest Service, have failed miserably to meet this mandate of the law.

The only course left to agencies is to place severe limits on the number of people who can use a wilderness area in a given point of time. Public use should be governed by first determining the wilderness character (what are we charged with preserving?) and then managing public use to fit it. Many people will resist such a change as interfering with their freedom of movement, but such action is inevitable if wilderness, as defined in the Wilderness Act, is to survive beyond the present generation of users.

One might ask, why hasn't the Congress provided leadership in this area of concern? One reason is that the Congress has been preoccupied with placing units into the NWPS. Another reason is that there has not been a public outcry on this subject, and there may not be until the issue of overuse virtually starts to destroy certain wilderness areas.

4. *Defending the Wilderness System.*—Citizen conservationists will be faced with a formidable task in the future—defending units of the NWPS (and the system itself) from intrusion and subsequent downgrading to a point where a wilderness area is wilderness in name only.

Already signs leading to this unfortunate situation are becoming more apparent. It has been only through the resistance of the Congress that proposals advanced by special interest groups thus far have been modified or rejected.

As we have seen, since 1968 the Congress has focused on correcting the "purity doctrine" of the wilderness management agencies, particularly the Forest Service. Virtually every Committee Report on a wilderness bill contains a directive to an agency concerning boundaries which were adjusted, inclusion of the works of man, permitted uses, and so on. In each case the focus has been on a "management exception," in the view of the agency. Only rarely has a clarification been placed in the law. The so-called Eastern Wilderness Act and the Endangered American Wilderness Act were enacted partially to alleviate the frustration of members who felt that they were being asked over and over again to solve a management dilemma which had been solved previously.

In the late 1970's it became apparent that, despite committee report language to the contrary, the Forest Service was overly restrictive in its interpretation of the Wilderness Act's mandate that previously existing livestock grazing would continue. In the RARE II process, operators became extremely concerned, fearing that livestock either would be gradually phased out of wilderness or operations would be so restricted that continued use would not be feasible. Tired of seemingly always having to address this issue on a piecemeal basis, the Congress responded to these concerns by enacting the Colorado Wilderness Bill in 1980 in which report language, applying to all National Forest areas, was referenced and mandated in the law. The intent of this approach was to clarify the intent of the Congress when the Wilderness Act was being debated some 20 years before, and a compromise to permit previously existing grazing to continue was agreed to.

Clarification of the intent of Congress relative to language in existing law is a horse of an entirely different color than the demands of other special interest organizations. Not being satisfied with boundary adjustments by the Forest Service or the Congress to accommodate their concerns, bicyclists have requested that the Wilderness Act be reinterpreted so that bicycles are not "mechanical transport"; off-road vehicle enthusiasts have asked that snowmobiles be made an "exception" to the prohibition on use of motor vehicles, claiming that such use would be compatible with wilderness because the season of use occurs during that part of the year when all other uses are nonexistent; livestock interests have demanded that language be included permitting predator control programs to continue in wilderness; boundary adjustments have been made by Congress to accommodate the mineral industry no matter how remote the possibilities of a major "find" might be (requests to amend the mineral provisions to permit "temporary" exploration have been rejected in favor of boundary changes); fish and wildlife management representatives have proposed that "management principles" be enacted to "clarify" activities which would be permissible in National Forest wilderness (actually a stalking horse designed to settle what these people see as a fish and wildlife jurisdictional problem. The guidelines could, under one interpretation, permit a game warden to go roaring around in a jeep, checking fishing licenses in a wilderness); ski resort development interests have proposed boundary adjustments to accommodate their proposals, with modest results; the current wilderness water right debate is not only based in an antiwilderness bias, but intends to "clarify" water rights in wilderness by sacrificing them; and so on.

WHAT'S IN THE FUTURE?

So, what does the future hold? Isn't it obvious that as the years pass more and more special interests will be pressing for more and more "exceptions" to accommodate their concerns and objectives? With the exception of the livestock interests (and they were on solid footing, since the Congress merely addressed in greater detail what the provisions of Sec. (4)(d)(4)(2) relative to previously existing livestock grazing mean), none of the other pressure groups has been successful in attempting to amend the Wilderness Act—to date, that is. But as time goes on and, in the event that the current view of wilderness as being only a recreation area should continue unabated, it is a foregone conclusion that enough pressure will be brought to bear on the Congress to enact legislation permitting activities that are not only incompatible today, but illegal. "What we

propose will not interfere with existing public uses, Mr. Chairman, but actually will enhance the wilderness experience for thousands of people who cannot use the wilderness now." Even worse, if this kind of wilderness future should come true, a wilderness area, presently the Nation's highest form of land dedication, will become a second-class land form, simply because all sorts of activities will be permitted in wilderness, by law, which are not allowed on public lands outside wilderness, by law.

Only through a well-informed, active, articulate citizenry speaking out in defense of wilderness (untrammeled wilderness, not a recreation area alone) will this future be forgone.

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PERSPECTIVES ON THE HISTORY OF WILDERNESS RESEARCH

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ABSTRACT

Wilderness management-oriented research was almost nonexistent before 1960. About then, recognition of the need for research knowledge to support management and protection of wilderness resulted in studies by Federal, private, and university scientists. Early research was exploratory, largely descriptive, and somewhat naive, but it was an exciting period. By the late 1960's, research efforts matured, and became more theoretical and interdisciplinary. The size of the wilderness research effort grew through about 1978 and has since declined. Early research stressed physical-biological studies of recreation impacts, but the emphasis quickly shifted to visitor studies. Carrying capacity was a major focus. The limits of acceptable change system was developed to deal with the carrying capacity issue. To maximize the contribution of a smaller research effort to protection of the large wilderness system, five recommendations are made.

INTRODUCTION

I have been deeply involved in wilderness research since the late 1950's, and I think that gives me the privilege of presenting a somewhat personal, impressionistic view of the history of wilderness research. I hope this will help us all see where we have come from and be of some value to us in dealing with future challenges.

I will cover three main topics: first, the chronology of wilderness management research, including general trends and research institutional developments; second, trends in the size of the research effort; third, major research themes or topics studied so far. In other words, we will cover the "when," the "how much," and the "what." It is not my intention to present a thorough literature review, to discuss specific results of research, or to list all the persons who have contributed. The nine state-of-the-art review papers at this conference do that much better and in detail. This paper may help set the stage for those reviews, which describe what we have learned and what important questions need answers. I will also briefly review the application of research to wilderness management.

Wilderness research is of two different types—"in wilderness" and "about wilderness." The first, "in wilderness" research, uses wilderness as a setting or laboratory for a variety of research, most of it in the biological and earth sciences. It is not directly focused on wilderness management issues. Most of it can be described as relatively basic research, and can be traced back at least as far as Lewis and Clark and Audubon. John Muir did some of this type of research on glaciation in the Sierra Nevada range. Preserving opportunities for this type of research is one of the important values of wilderness and one of the explicit purposes listed in the Wilderness Act (Public Law 88—577).

The second type of research, "about wilderness," is focused on wilderness management issues, and is relatively applied. It seeks to provide managers with improved knowledge for making effective decisions to protect and preserve the wilderness character of areas in the National Wilderness Preservation System, as they are required to do by the Wilderness Act. Such research also seems related to one purpose of wilderness areas listed in the Act, "the gathering and dissemination of information regarding their use and enjoyment as wilderness." This research deals with topics such as wilderness fire management, control of visitor impacts, wilderness recreation experiences, and visitor management.

This paper will concentrate on the management-oriented, "about wilderness," research. There are borderline cases. The distinction between the two types of research is not always clear, and more of the "in wilderness" research could contribute to management if researchers would highlight management implications of their studies when appropriate. I will aim to err on the inclusive side. Some research conducted outside wilderness, and some done outside the United States, is relevant to management of wilderness and examples will be discussed without pretending to be exhaustive. "Wilderness" will be used in a rather broad, generic sense, not limited strictly to American wilderness classified under the Wilderness Act, although that is the primary focus.

PRE-WILDERNESS ACT BEGINNINGS

Formal wilderness designations did not exist before 1924 when the Gila Wilderness was established by the Forest Service. There have been national parks since 1872 when Yellowstone was designated, but without any specific wilderness direction (Nash 1978). Wilderness preservation in a national park was first mentioned in the act establishing Everglades National Park in 1934. There seems to have been no research and almost no recognition of the need for research to support wilderness management at first. In fact, except for developing and maintaining trail systems, usually more for administration and fire protection than visitor use, there was little management of wilderness.

Bob Marshall, the prime mover behind development of the National Forest wilderness program in the 1930's, was one of the first to recognize that establishing wilderness was not the only issue; management also was necessary. He commented on overused campsites and the need for visitor education in what we would now call minimum impact camping in 1933 (Nash 1978). In 1937,

Marshall requested a University of California professor (who was also president of the Sierra Club) to form a committee of scientists to advise the Forest Service on wilderness management, which might have served a purpose similar to research. Another of the early recognitions of issues needing study was by Lowell Sumner of the National Park Service who expressed concern about the impacts of recreational use in 1936 and raised the question of recreational carrying capacity in 1942 (Nash 1978).

There were only a few scattered wilderness research studies before 1960. George Wright and his colleagues in the National Park Service began wildlife research in the late 1920's, and a fauna series was published. Wright and others (1933) dealt with general wildlife relationships in national parks. Others covered individual or related species, for example, Adolph Murie's "The Wolves of Mount McKinley" (1944). Outside wilderness, but of some relevance, was research on the effects of visitor trampling on vegetation. Probably the first was work by H. L. Meinicke in the redwoods in 1928. In the 1930's, trampling studies were conducted in Great Britain by Bates (1935), among others. A 1954 Ph.D. dissertation by James Gilligan analyzed the evolution of Forest Service wilderness policy in detail, and may even have contributed to introduction of the first wilderness bill in 1956.

In the late 1950's, interest in outdoor recreation, and recreation research in general, grew rapidly. Recreation use was growing fast, even explosively in the view of many. Developed recreation facilities, many of which had been built in the 1930's by the Civilian Conservation Corps, were aging and deteriorating. Because of these conditions, the National Park Service launched "Mission 66" in 1956, a 10-year capital investment program to renovate, replace, and expand buildings, campgrounds, and other facilities. The Forest Service followed suit with the similar "Operation Outdoors" the next year.

Both of these major recreation investment programs were launched with no recreation research knowledge base at all. Resource inventories and visitor desires both were handled on a best-guess basis. Perhaps because some policymakers were uneasy about the knowledge gap, the Forest Service commissioned Samuel Dana, Dean Emeritus of the University of Michigan School of Natural Resources, to prepare a problem analysis for research in forest recreation (Dana 1957). This was the result of a recommendation by a U.S. Department of Agriculture Forest Research Advisory Committee, on which Dana also served, that research on forest recreation be stressed. Dana was not a recreation research specialist; nobody was then. However, he wrote a perceptive report. Some of his terminology differs from current jargon, but his analysis is not badly dated even now.

About the same time, Marion Clawson of Resources for the Future, one of the pioneers of recreation research, published "Statistics on Outdoor Recreation" (Clawson 1958). This publication brought together scattered data, primarily on recreational use, for State and Federal lands for the first time. Increasing use was documented, and this captured the interest of a number of people. Clawson also published his influential travel-cost method for measuring recreation demand and value (1959). This and a number of popular articles by such a respected scientist helped build support for research on outdoor recreation.

Also in the 1950's, the very first studies of wilderness visitors and their motives and opinions were done in Minnesota's Boundary Waters Canoe Area by University of Minnesota sociologists (Stone and Taves 1956).

The Sierra Club's Sixth Biennial Wilderness Conference in 1959 addressed "The Meaning of Wilderness to Science" (Brower 1960). As the title suggests, many of the papers dealt with the value of wilderness as a research laboratory, a point made by Aldo Leopold in 1941, but there was recognition in several papers of the need for ecological research to help deal with growing problems of recreational use pressures. Research on visitors was mentioned only briefly in the conferees' discussion relating to one paper.

In 1958, the Outdoor Recreation Resources Review Commission (ORRRC) was established by Congress. This was a major program and reflected the growing public interest in outdoor recreation and the need for an information base for informed decisions. The commission's main summary report in 1962 was accompanied by 27 special study volumes—about 1 foot on the bookshelf. The stimulating effect on interest in outdoor recreation and research produced by this mass of data and analysis at the time is hard to imagine now. There was so little previous scientific literature that these 27 volumes increased available information at least severalfold.

ORRRC Report No. 3 (ORRRC 1962) focused on wilderness. It was prepared by the University of California Berkeley Wildland Research Center, directed by James Gilligan, author of the wilderness policy dissertation discussed before. One of the longer reports, it included historical and policy analysis and data from visitor surveys in three wilderness-type areas. Again, it loomed large in the near vacuum that existed at that time.

THE ACT AND NEW RESEARCH PROGRAMS

Various wilderness bills, 65 in all, were debated in Congress from 1956 to 1964, when the Wilderness Act finally passed. ORRRC Report No. 3, the wilderness volume, recommended passage of a wilderness act. I do not know if that recommendation is related to the odd fact that the wilderness volume alone among the 27 special study reports had to be printed with contributed private funds.

The Wilderness Act does not refer to research explicitly, although the reference previously cited to "gathering and dissemination of information regarding their use and enjoyment as wilderness" can be read as implying research. On the other hand, it probably could be read as implying preparation of brochures on how to visit a wilderness. I have not found anything that clarifies the intent of Congress. Scientific, educational, and historical use are among the authorized uses of wilderness. The first two, at least, are consistent with research. (The meaning of "historical use" is unclear to

me, but it could include historical research, as well as viewing historic sites.) I could not find anything in the legislative history that refers to research to support management, although there is testimony about the value of wilderness as a research laboratory—the type of research I have dubbed "in wilderness." Clearly, however, if managers are to meet the challenge of the Wilderness Act to administer wilderness for "use and enjoyment of the American people," to "leave them unimpaired for future use and enjoyment as wilderness," "provide for the protection of these areas," and "the preservation of their wilderness character" some support from research appears to be implied.

In 1959-60, while the Wilderness Act was about halfway through its debate, the Forest Service began its recreation research program (Camp 1984). This was the first tangible recognition of the need for a continuing research program oriented to recreation management issues.

None of the research units at different locations in eight forest experiment stations had wilderness management specifically as a mission at this time, although this was a major part of the early research program at the Pacific Northwest Forest and Range Experiment Station in Portland, OR, where the first research unit was entitled "Wilderness Dynamics." The first wilderness use measurement research (Wenger 1964), and some visitor survey research (Burch and Wenger 1967) were done by this unit. Several other units did some research on wilderness problems in the early years: the North Central Forest Experiment Station (then called Lake States) began with research on use/user characteristics as related to carrying capacity in the Boundary Waters Canoe Area (Lucas 1964), and followed up with fire history (Heinselman 1973) and ecosystem classification studies (Ohmann 1971). The carrying capacity concept presented by Alan Wagar (1964) of the Intermountain Forest and Range Experiment Station was not limited to wilderness but was particularly applicable there. The Northeastern Station began studies of vegetation impacts from heavy use (Ketchledge and Leonard 1970) and visitor attitudes about heavy use in backcountry (Echelberger and others 1974). Thus, wilderness research by the Forest Service began before passage of the Wilderness Act.

The Forest Service also began outdoor recreation cooperative units at five universities in the early 1960's (Camp 1984). These usually consisted of one Forest Service scientist placed in a natural resource or forestry school to stimulate interest (especially by faculty and graduate students), to provide professional leadership in outdoor recreation, and to help train future outdoor recreation managers. The units were modeled somewhat after the Fish and Wildlife Service's cooperative research units. Financial support for university research projects was channeled through these recreation co-op units, some of it wilderness related. Most of the Forest Service scientists did some teaching and student advising. The intent was to fill a near vacuum of recreation expertise in natural resource faculties and to accelerate development of such skills. The Forest Service also foresaw a need for a large number of employees with professional training in outdoor recreation that they felt would not be met without a special program.

At this time, the National Park Service research program was primarily conducted by scientists assigned to individual parks. Most of it seems to have been quite applied, serving largely as staff work for the park line officers. Unfortunately, much was unpublished, and other scientists were seldom able to build on the work. A large part was wildlife research for management decisions and information for interpretation. Some was natural history, geological, historical, or prehistorical research.

This period of the early 1960's was a time of excitement associated with new beginnings, idealism, and a certain amount of naiveté. Outdoor recreation grew in recognition as an important program, although there was still some insecurity about the respectability of studying a noncommodity output that was not generally viewed as a necessity of life. Researchers had high hopes of providing solid answers to basic, usually rather simple questions, such as "what do people want?", "how much use is too much?", and so on. It really was great fun!

Many disciplines were involved: social sciences, biological sciences, and forestry, which was primarily biological in orientation within a professional management program. There was a considerable amount of trial and error, not a great deal of coordination, and some scattering of efforts that was probably inevitable in the newness of the effort, and perhaps necessary to start the development of concepts and structure for research. At this early stage, there were no journals focused on outdoor recreation research. This contributed to the limited coordination and scattering of efforts, especially with so many disciplines involved.

By the late 1960's or early 1970's, the early research efforts evolved and matured into what seems to me to have been a stronger, more coordinated and coherent program. The simplicity and naiveté were replaced with more recognition of the complexity of the issues and the elusiveness of simple, easy answers, magic numbers, and the like. Recreation managers were also becoming more professional and knowledgeable. This resulted in more productive interaction between managers and researchers.

The National Park Service began to play a more prominent role in wilderness research in this period. The first permanent, full-time research sociologist, Neil Cheek, joined the Park Service in 1968. In 1970 the first of the cooperative park studies units (CPSU) was established at the University of Washington (Agee and others 1982-1983), led by Don Field. The number of these research units has grown to 35, and about 15 have a resident Park Service scientist. These are located in all parts of the country, but are most common in the West.

The CPSU's have similarities to the Forest Service cooperative units beyond the name, but major differences as well. The Forest Service units were meant to serve the temporary needs of the universities, and when those needs were met by the late 1960's, as the universities developed their own expertise, the units were phased out. In contrast, the Park Service CPSU's primary function is to meet the research needs of the national parks

(Agee and others 1982-1983). Teaching and extension are also outputs from the CPSU's, but research to meet the needs of individual national parks and general problems of groups of parks is uppermost. Research is done not only by National Park Service scientists but also cooperatively by university scientists with appropriate skills and interests. Some has involved cooperation with Forest Service researchers, and this has led to research on regional recreation systems, cutting across agency boundaries, in Alaska, for example (Clark and others 1982). Some of this research relates directly to wilderness; for example, a series of visitor studies in Alaska (Womble and others 1978). Systems for handling backcountry permit data were also developed (Field and others 1977).

In 1967 the first and only research unit with wilderness management as its sole mission was established by the Forest Service in Missoula, MT, as part of the research program of the Intermountain Forest and Range Experiment Station. It was staffed by George Stankey and I, and later, for a time, by Randy Washburne, David Cole, and Margaret Petersen. The major focus has been visitor management research, including descriptive surveys, social carrying capacity studies, use measurement methods, redistribution of use through information, use and encounter simulation models, and management systems, such as the Recreation Opportunity Spectrum and Limits of Acceptable Change. Ecological impact research was begun in 1978 when David Cole joined the unit on a temporary appointment and has continued through cooperative research after his appointment ended. This research program is reviewed in Lucas and others (1985).

There was also some wilderness research by other Forest Service recreation research units, as part of their research program missions, although none was directly focused on wilderness. At the Rocky Mountain Station, Bev Driver's work on experience preferences or motivations, some of it in cooperation with Perry Brown and others at Colorado State University, was applied to wilderness visitors in Colorado and Wyoming (Brown and Haas 1980), and to an integrated management planning pilot project for the Maroon Bells-Snowmass Wilderness in Colorado. At the Northeastern Forest Experiment Station, Ray Leonard studied recreational impacts on soils (Leonard and Plumley 1979a) and capacity concepts (Leonard 1976), and Skip Echelberger and George Moeller did wilderness visitor surveys (Echelberger and Moeller 1977). At the North Central Station, Dave Lime and cooperator George Peterson did further research in the Boundary Waters Canoe Area on use patterns (Lime 1972), visitor expectations and preferences (Peterson 1974), use estimation (Lime and Lorence 1974), and simulation models. Dorothy Anderson studied displacement-succession (Anderson 1980). George James at the Southeastern Station included wilderness in a continuing program of recreational use measurement research (James 1971). At the Pacific Northwest Station, John Hendee and Roger Clark did wilderness-related research, including a study of visitor characteristics and attitudes in three Washington and Oregon wildernesses (Hendee and others 1968), littering behavior in wilderness (Muth and Clark 1978), and surveys of southeast Alaskan recreationists (Clark and others 1982).

The Park Service wilderness-related research concentrated on natural sciences—botany, zoology, ecology—while Forest Service research focused on recreation use (Butler and Roberts, this proceedings).

Resources for the Future continued to be active in recreation and wilderness research, particularly opportunity costs of development of natural areas (Krutilla and Cicchetti 1972) and wilderness use simulation (Shechter and Lucas 1978).

Conservation organizations also contributed to early research. The Appalachian Mountain Club established a research department and began study of social and ecological problems (for example, Taylor and Mackoy 1980). The Sierra Club sponsored a group of studies on recreation impacts in the Sierra Nevadas in the early 1970's (Stanley and others 1979).

Strong university research involvement developed at a number of places. At risk of offending someone by omission, wilderness-related research comes to mind at such universities as Colorado State, Washington, Michigan, Virginia Polytechnic, Utah State, Minnesota, Vermont, Oregon State, Texas A&M, Idaho, Montana, and Montana State. Most of this research activity centered around forestry and natural resource schools, but it also involved park and recreation departments, and geography, psychology, sociology, economics, botany, and zoology. A wide variety of topics related to wilderness have been studied. Publications have appeared in many different journals and other outlets, but it is my impression that social science or visitor studies have predominated strongly, with fire and visitor impacts well behind.

The first recreation research journals appeared. None focused on wilderness, but they included wilderness research. First was the *Journal of Leisure Research* in 1969, then *Leisure Sciences* in 1977. Several new journals with a biological, environmental, conservation emphasis also appeared in this period, although none of them provided as much of a forum for wilderness-related research as the two essentially social science journals. In 1981, *Pacific Park Science*, published by the National Park Service, went national and became *Park Science*. At present, its focus is on national park management and most contributors are National Park Service employees. This leaves a gap; there is no journal aimed at wilderness managers. The *Journal of Forestry*, particularly, and the *Journal of Soil and Water Conservation* have been the primary outlets for articles written for wilderness managers.

SIZE OF RESEARCH EFFORT

The wilderness-related research effort began from scratch about 1960. I will use Forest Service recreation research as a handy example because it was the first separate, discrete program; it has a readily identifiable budget; and has involved a substantial amount of research on wilderness topics over the years. Growth from 1960 through the middle 1970's was rapid and fairly steady, increasing about ninefold in budgets (fig. 1) and with a smaller but substantial growth in staff. Then,

in 1978, the recreation research program doubled, and urban forestry research was initiated and added to the recreation research program. The budget peaked in 1979 at about $3.3 million. After this one brief, euphoric burst of growth, it has been all downhill, although irregularly, declining about 40 percent from 1979 to 1985. Staffs have declined only slightly, and, as a result, operating budgets for field research and cooperative studies with university scientists have plummeted.

The Forest Service wilderness management research unit began in 1967 in Missoula, MT. The changes in its size have followed a path similar to that for recreation research in general—fairly steady growth through 1977, then nearly a doubling in 1978 to a high of $310,000, followed by a decline of about 45 percent (fig. 1). Staff grew from two to five and now is back down to two. All budget figures are in nominal dollars. Adjustments for inflation diminish earlier growth and accentuate later declines. Using constant 1982 dollars (GNP price deflator), the budget grew 61 percent from 1968 to 1977, grew 64 percent from 1977 to 1978, and declined 57 percent from 1978 to 1985.

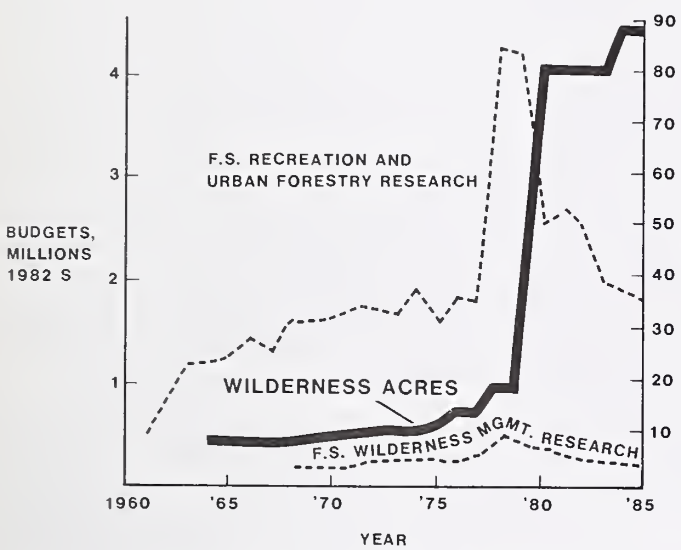

Figure 1.—Trends in size of the National Wilderness Preservation System and budgets for related Forest Service research.

The National Park Service research program in the parks and at the cooperative park studies units grew in the 1970's and has been relatively stable since then. The Cooperative Park Studies Units contract for over $1 million of research per year, on the average (Agee and others 1982-1983).

Research budgets for the national parks apparently have fared better in recent years than those in the Forest Service. One might speculate that this reflects the close link to park management needs contrasted to the more independent role played by Forest Service research.

University wilderness research is too widespread and diverse to be tallied and quantified. However, it probably followed somewhat the same pattern of growth until the late 1970's and decline since then, less extremely than Forest Service wilderness research. Numbers of professors involved in wilderness research, amount of faculty time, and numbers of graduate students also first grew, then leveled off, and declined. Contract and grant sources and funds for cooperative research that support much of the university wilderness research all grew and now have been declining for 5 years or more.

It seems only reasonable to presume that the production of new knowledge, solution of important problems, and technology transfer from researchers to managers reflect in general the resources devoted to wilderness-related research, and therefore these also rose and then declined.

In sharp contrast to the recent decline in wilderness research, the size of the wilderness system has grown greatly, from 9 million acres in 1964 when the Wilderness Act passed, to over 88 million acres early in 1985 (fig. 1). Assuming total expenditures by all agencies and universities for wilderness-related research are five times the budget of the Forest Service wilderness management research unit, about $0.09 (1982 dollars) was spent per acre of wilderness in the late 1960's. In 1985, about $0.01 per acre of wilderness is being invested in research for wilderness management and protection. By my estimate, commercial timberland research amounts to $0.50 or more per acre. I do not believe the relative values at stake, the difficulties of management, or the adequacy of existing knowledge for timberland management compared to wilderness protection justify this wide disparity. Managing wilderness to do an acceptable job of protecting it and producing benefits for society will require a larger research effort.

MAJOR RESEARCH THEMES

I will divide the discussion of research themes into two periods, the early period from about 1960 through the early 1970's, and the late period from the early 1970's to 1985. (Because the lag between research and publication varies widely, some of the studies I call "early" have publication dates past the early 1970's.)

The Early Period

In general, the earliest outdoor recreation research was exploratory. There was considerable uncertainty about what the problems really were and what research approaches were appropriate. Concepts and theories were absent from most of the studies, implicit in some, and explicit and formal in only a few.

As was appropriate at this early stage, much of the research was largely descriptive, providing reliable information about wilderness recreation characteristics, patterns, and effects. However, it is unfair to describe most of this research as "mere description" or "purely descriptive." From the first, many of the studies went beyond description to analyze relationships and offer explanations. Basic descriptions also were an essential foundation, I think, to the more specialized, sophisticated research that followed.

Physical and Biological Research.—Biophysical research on ecological processes and visitor impacts began early, and was stressed more than visitor research initially. Most of the first impact research was conducted at developed recreation sites, mainly camp-

grounds and picnic areas, rather than wilderness (for example, LaPage 1962). This served to develop techniques and concepts that were applied later to wilderness settings.

Soon research in backcountry dispersed recreation settings, including wilderness, began to address wilderness management topics more directly. Much of it dealt with impacts, mainly to vegetation, and with the role of natural fire in wilderness ecosystems.

Early impact research made limited use of range management science for principles and approaches to studying vegetative disturbance. There was a little research on the effects of grazing by recreational stock (Sharsmith 1959), but campsite conditions were the main focus of impact research, with trail conditions receiving somewhat less attention. Most studies were mainly attempts to document impacts in a systematic, accurate way (see the annotations of studies in Cole and Schreiner 1981). A few attempted to relate impacts to site conditions such as forest versus meadow and degree of closure of forest canopy (Schreiner and Moorhead 1976), and even fewer dealt with amount of use (Frissell and Duncan 1965). Most of the campsite studies were based on measurement of conditions on already existing sites. One exception was a study of newly created campsites in the Boundary Waters Canoe Area (Merriam and Smith 1974). Vegetation impacts were the main concern, with lesser attention to soil compaction. There were also several studies that applied experimental trampling to vegetation (Bell and Bliss 1973). Research on trail erosion almost always dealt with conditions on existing trails. One of the earliest trail erosion studies was conducted in the Adirondack Mountains of New York by Ketchledge and Leonard (1970). A review of research on the ecological effects of outdoor recreation by Speight (1973) summarizes much of the early period impact research. Almost 200 publications were reviewed from Britain, western Europe, and North America.

Many ecological and impact topics received very little attention in the early period. Impacts of recreational use on water quality were only rarely studied (Barton 1969). Recreational impacts on wildlife, other than the direct effects of hunting and fishing, were almost unstudied. There was a large amount of general wildlife research, some of it conducted in wilderness. This research dealt with issues such as home ranges, movement, feeding behavior, reproduction rates, and so on, much of which is relevant to perpetuation of natural populations. This research contributes at least generally to wilderness management decisions. Examples include research on moose-wolf relationships on Isle Royale (Mech 1966); mountain lions in the Idaho Primitive Area (Hornocker 1969); and grizzly bears in Yellowstone National Park (Craighead and others 1974). Studies of recovery of vegetation from the effects of recreational use were largely missing during this early stage, as was research on air quality.

Some research on plant succession was done in the early period. Very early research examined succession in mountain meadows in California (Sharsmith 1959). Most of this early research focused on plant succession in relation to natural fire. Fire history studies were fairly common near the end of the early period, including Sequoia-Kings Canyon National Park in California (Kilgore 1973); the Selway-Bitterroot Wilderness in Idaho (Habeck 1972); Glacier National Park, MT (Habeck 1968); Yellowstone National Park, WY (Houston 1973); Everglades National Park, FL (Robertson 1962); and the Boundary Waters Canoe Area, MN (Heinselman 1973). Research on fire's natural role resulted in the rapid evolution of agency policy toward restoration of natural fire in wilderness. To date, this probably is the most conspicuous example of the application of research results to wilderness management.

Physical-biological research on wilderness impacts and ecological processes in the early period was concentrated in the mountain landscapes of the West, including western Canada, and in northern Minnesota. There were a few studies in New England, most by Ray Leonard, and, later, in the Southeast. (Other research was conducted overseas, in Great Britain, western Europe, and Japan.) There was almost no research in deserts, grasslands, or river corridors at this time.

Almost all studies were one-time descriptions; longer term trend studies were very scarce.

Social Research.—Social research on visitor use patterns, attitudes, activities, and demographic characteristics began in the early period, with attitudes receiving particular emphasis. Visitor surveys were fairly common, although the scientists carrying them out had to contend with difficult sampling and data collection problems (Lucas and Oltman 1971): users were widely dispersed, relatively few, and highly variable in number, all resulting in high sampling costs, small samples, and large variances. For example, the wilderness report by ORRRC (1962) described their attempts to survey visitors to seven wildernesses, but they obtained samples large enough to analyze in only three areas. The potential for interference with visitors' wilderness experiences also limited some approaches to collecting information.

Most of the wilderness visitor surveys were more than purely descriptive "census reports." Data were analyzed in terms of types of use and characteristics of visitors, as well as attitudes, such as Hendee's "wilderness purism" scale (Hendee and others 1968). The surveys helped clarify the nature of wilderness recreation, and indicated the limited truth of a number of common misconceptions about wilderness use and users (Stankey 1971).

Early visitor surveys provided a general picture of wilderness visitors (Lucas 1964; Hendee and others 1968; Murray 1974). Visitor characteristics tended to be similar in many wildernesses, but activities and behavior were more variable and site specific. The most distinguishing characteristic of wilderness visitors in every study was high education levels.

Use measurement methods received considerable research emphasis during this early time. Much of this research was done by Jim James from the Forest Service Southeastern Forest Experiment Station (James 1971). Reasonably accurate, cost-effective, practical techniques for measuring wilderness recreational use were needed to provide data that are basic both to skilled professional management and to many types of research. Most of the research dealt with systems for calculating

use estimates based on trail register data or various types of traffic counters. Computerized systems for summarizing wilderness permit information were developed (Elsner 1972; Frayer and Butts 1974; Field and others 1977).

The wilderness use measurement research was a part of a more general effort to develop recreation use measurement systems, including systems for developed sites of various kinds. Usable methods were developed for campgrounds in particular, and incorporated into widely used handbooks. This did not happen for wilderness use estimation, which was more difficult and expensive, for much the same reasons mentioned in connection with visitor surveys. The problem was potentially solvable to a greater degree than many other wilderness research topics, but it did not receive enough effort long enough to finish the job and produce completed technology for transfer to managers. James retired and research to develop an integrated wilderness use measurement program was dropped shortly after.

Carrying capacity was one of the major themes of research in the early period. Research focused on concepts or approaches to carrying capacity (Wagar 1964; Lime and Stankey 1971; Frissell and Stankey 1972). Very early physical-biological capacity was emphasized, but social carrying capacity quickly replaced it as the main thrust of research, with stress on investigations of the solitude dimension of wilderness experiences and visitor standards for solitude (Lucas 1964; Stankey 1973). The important role of the human dimensions of wilderness management is another research output adopted by managers, gradually but widely. This concept is so generally accepted now that its origin in research is no longer recognized.

The social carrying capacity studies laid down many principles that later research confirmed. Results indicated that satisfactions depend on more than use level, particularly on type, frequency, and location of encounters. It was recognized early that capacity had to be related to management objectives.

There was some early emphasis on economic research; most focused on outdoor recreation in general, but some related to wilderness. Much of this early economic research is discussed in Clawson and Knetsch (1966). Part was concerned with general economic values. Another part dealt with demand, travel cost models to estimate demand for and value of individual areas, gravity models, and intervening opportunity analyses to attempt to explain and predict use of specific areas, and economic impacts on local regions.

There were other topics addressed by a study or two; for example, Nash's classic work on the intellectual history of wilderness, first in *Forest History* (1963), then in a major book (1982—with the first edition published in 1967), or Hughes' (1965) study of wilderness land allocation.

Early social research, like physical-biological research, also was concentrated in the West and the Boundary Waters Canoe Area-Quetico Park region. There was a little in New England and eastern Canada. There was considerable social recreation research in Canada, some of it wilderness related; for example, see the wilderness bibliography by Herrick (1974).

Little or no early research was conducted on wilderness visitor education/information programs (although there was a little in nonwilderness situations). No general population studies were related to wilderness; all the studies were based on samples of current on-site visitors. There were no trend studies; all of the visitor research was based on one-time surveys.

The Late Period

After the early 1970's, wilderness studies became more narrowly focused and more scientifically rigorous. There was more conscious effort to develop theories, concepts, and models. Samples were better designed and multivariate statistics were used more in analysis.

As many different disciplines were involved as before, but there was at least a little more communication and collaboration and less "go it alone" research. Communication was enhanced by the new journals (*Journal of Leisure Research, Leisure Sciences, Environment and Behavior, Environmental Conservation, Journal of Environmental Education, Park Science,* and so on), and more review bibliographies. Conferences and symposia focused on wilderness also furthered collaboration. Conferences included wilderness management meetings in Seattle in 1973 and at the University of Idaho in 1983, a wildlands recreation impact conference in Seattle in 1978, conferences on wilderness in the East held in Knoxville in 1980 and Nacodoches, TX, in 1985, a wilderness fire symposium in Missoula in 1983, and World Wilderness Congresses in 1977, 1980, and 1984 in South Africa, Australia, and Scotland. Other conferences were not focused just on wilderness but included many wilderness concerns; for example, the wildland recreation conference in Banff National Park (Canada) in 1978, river recreation conferences in Minneapolis in 1977 and Baton Rouge in 1984, the trends symposia in Durham, NH, in 1980 and Myrtle Beach, SC, in 1985, and conferences on scientific research in the national parks held in New Orleans in 1976 and San Francisco in 1979.

Biophysical research on impacts and ecological processes continued, but the balance between visitor studies and biophysical research shifted in the early period toward visitor studies. The view that visitor research should receive higher priority was widely adopted. Reasons included the belief that less was known about visitors in comparison to biophysical processes, change affecting visitors was more rapid, potential consequences were more serious, and that wilderness management is largely people management. All these were probably true at the time, but the pendulum, in my view (and I am a social scientist), swung too far away from research on interactions between visitors and soils, vegetation, water, and wildlife, particularly, and has stayed away too long. Except for natural fire research, there were too few biophysical scientists and too little wilderness-related research in most of this period to achieve a "critical mass." Unlike social researchers, there were few biophysical scientists deeply involved in wilderness research and few careers devoted to it.

Physical and Biological Research.—Campsite impacts received major emphasis in biophysical research

in this period, as they did earlier. Research revealed the complexity of the impact process and its management. The relatively minor role of total amount of use in determining impacts became clearer (Marion and Merriam 1985; Cole 1982). Campsite condition rating systems were developed. One by Frissell (1978) was widely used, as was the monitoring approach developed by Cole (1983a). Sometimes the two systems were combined, and occasionally integrated into the Code-a-site campsite inventory data management system (Hendee and others 1976).

There was considerable research on trail conditions. It became clear that heavy use was not the main cause of trail deterioration. Location, design, maintenance, and type of use were more important (Helgath 1975, for example). Monitoring techniques for trails were developed (Leonard and Whitney 1977; Cole 1983b). Application of research to trail management has lagged, in large part due to the decline in major trail work as wilderness management budgets have dropped.

Other research dealt with vegetation recovery and rehabilitation of campsites particularly, and trails to a lesser extent. An annotated bibliography by Cole and Schreiner (1981) indicates the scope of this research.

Impacts of recreational use on wildlife, primarily disturbance and indirect effects on habitat rather than hunting or fishing, received some attention in the later period, as documented in an annotated bibliography by Ream (1980), but knowledge gaps for this topic remain severe. There also was a continuation of more general, basic wildlife studies, usually of individual species (such as eagles, grizzly bears, wolves), much of it by National Park Service scientists and cooperators.

Some water quality research was conducted in this period, as is apparent from the studies reviewed by Christensen and others (1979). There also were several studies of human sanitation under wilderness conditions (Leonard and Plumley 1979b; Temple and others 1980, 1982).

Only very recently has there been any research on air quality as it affects wilderness; for example, research on the effect of air pollution on vegetation and water chemistry in progress in the Wind River Range, WY, and current studies of visibility changes as they affect visitors in Grand Canyon and Mesa Verde National Parks. A workshop addressed changes in air quality affecting the Flat Tops Wilderness in Colorado (Fox and others 1982) and Malm (1983) described the basic processes affecting visibility in relation to national parks. Rowe and Chestnut (1983) edited a series of papers on air quality in national parks and wilderness.

Fire research was emphasized in the later period, with accumulating knowledge on fuels, fire behavior, fire histories, and growing managerial experience in applying policies that helped permit fire more nearly to play its natural role in many wildernesses. Knowledge about wilderness fire was summarized in a major conference in Missoula in 1983, documenting major advances. Both the Forest Service and Park Service, as well as university scientists, were active in research on fire in this period.

There was still not much research on basic ecological processes (see the paper by Franklin in these proceedings). The overall knowledge base from impact research and more basic ecological research was still fairly weak and did not provide an adequate foundation for many recommended minimum impact visitor use practices suggested by managers and sometimes incorporated in regulations.

Social Research.—Social research shifted its focus more than biophysical research in the later period and also increased more. Visitor surveys became less common than earlier, and research related to development of use measurement methods diminished, with the problem still not quite solved. Objectives for measuring backcountry use and the advantages and disadvantages of the available technology were summarized by Leonard and others (1980). Social carrying capacity research grew, and intensive questioning of earlier formulations occurred (Graefe and others 1984). Earlier research had shown strong negative evaluations of increasing contact with other parties (Stankey 1973), but some later research showed little or no association of contacts and satisfaction, especially on rivers. A synthesis is emerging, drawing on ideas present, at least implicitly, in the earlier research (Stankey and McCool 1984). This approach takes into account individual variation in visitor motives, recognizes that seeking solitude is one of a number of motives, and views satisfaction as a complex concept, difficult to measure, and influenced positively and negatively by many factors in addition to number of encounters.

The issue behind all research activity concerned with carrying capacity was the question originally phrased as "How much use is too much?" Much carrying capacity research aspired to determine a maximum amount of use, without much success. Application lagged. But the basic question has gradually, over more than 10 years, been redefined and a solution proposed. The redefined question is "What sort of conditions resulting from use are acceptable?" It includes a concern for both biophysical and social conditions—in other words, for both visitor impacts and experiences. The related question of how to manage for capacity also shifted from a narrow focus on limiting or redistributing use to a broader array of management actions affecting visitor behavior as well as numbers and distributions.

The proposed solution is management within limits of acceptable change, or the LAC approach (Stankey and others 1985). With the clear vision of hindsight, LAC now seems so obvious to me, so practical and feasible, that it is hard to comprehend why it took so long for us to grasp it, especially since the basic ideas had been in the literature since the early 1970's (Frissell and Stankey 1972) and even before. Of course, many developments look simple in retrospect, and turning the basic idea into a coherent, sequential management system founded on research knowledge was a complex challenge. The LAC approach integrates social and ecological concerns, which has not been common. LAC may provide a vehicle for further collaboration and integration of social and biological research. Current applications of LAC (Stankey and others 1984) may indicate unforeseen prob-

lems and the need for further development, but this system seems to have the potential to become another major example of successful technology transfer.

Related to the concern for managing for carrying capacity, several simulation models of wilderness recreational use were developed in this period. One model relates number of groups entering at various access points to resulting use in travel zones. The numbers of campsites in each zone were compared to simulated use to establish entry point quotas that would not result in use exceeding campsite capacity (Peterson and others 1977). This model was developed for the Boundary Waters Canoe Area Wilderness and applied there. Another model simulates use levels and various types of encounters among visitors for specific locations (Shechter and Lucas 1978). It was applied by managers in California to develop use limits with minimal restriction of use and in Colorado to develop encounter standards and to select sites for use monitoring, and in teaching wilderness management (Manning and Potter 1984).

Benefits and values were studied more in this period, particularly in social-psychological terms. Attitude scales were constructed to measure a wide variety of motives or preferred outcomes, and were applied to many participants in a diverse range of activities in varied settings, including wilderness (for example, Brown and Haas 1980). General study of attitudes about wildlife and wildlife values also had some relevance to wilderness (Kellert 1976).

Economic analysis of values continued. Some of it focused specifically on wilderness (Walsh 1982, for example), some of it dealt with recreation and wildland values in general (Peterson and Randall 1984, for example). Opportunity costs of allocating forest land to wilderness were studied in southwestern Montana, where they were low, and western Oregon, where they were high (Campbell and Countryman 1981).

Some research explored means of changing problem behaviors, particularly littering, by using incentives or appeals, and part of this research has been applied to wilderness visitors (Muth and Clark 1978). Some related research tested the effect of various types of information on wilderness visitors' choices of when and where to visit (Lime and Lucas 1977; Lucas 1981; Krumpe and Brown 1982) and where to camp (Roggenbuck and Berrier 1982; Echelberger and others 1983). Information campaigns designed to cause wilderness visitors to adopt other minimum impact practices have scarcely been studied, however, despite the large amount of effort managers are putting into minimum impact education.

Trends have received little research attention (Lucas 1985 reviews the few trend studies done, and the National Park Service CPSU scientists are repeating some of the Alaska visitor surveys). Projections have been studied even less (Jungst and Countryman 1982).

RESEARCH APPLICATIONS

Wilderness managers have benefited substantially from a productive relationship with research. Some contributions are distinct and readily identified, others are more general concepts that have been widely adopted and whose roots in research are no longer obvious.

Among the more distinct research outputs are: wilderness fire management programs; campsite inventory systems; trail register systems; computerized use-data summary programs; general approaches to use measurement; equitable use-rationing systems; the basis for party size limits; simulation models used to ration use; advantages of education approaches (high visitor education levels and commitment to wilderness); use of information to redistribute use; the limits of acceptable change system; recognition of the ineffectiveness of campsite closure as a rehabilitation technique; identifying location, design, and maintenance of trails, rather than amount of use, as the keys to controlling deterioration; and many site-specific results.

Some of the broader, more general research concepts that now are part of the overall approach to wilderness management are that experiences are the major output of management, that diversity in experiences is essential, that visitor conflict is an important problem, that visitor displacement can occur, that wilderness management is largely visitor management, that objectives are critical to wilderness management, that wilderness use is very unevenly distributed geographically and over time, that nonregulatory management fits visitors' goals well, much of the concept of minimum impact use, recognition that carrying capacity involves social as well as ecological factors, the fact that most resource impacts result from light use, and the role of many factors besides amount of use in producing impacts.

Research contributions to wilderness management are presented in more depth in the book *Wilderness Management* (Hendee and others 1978).

The professional skill of wilderness managers has matured and grown over the last 20 years, with researchers' work contributing to this process. Managers' attitudes have also changed, for the better I feel. I recall early management meetings at which a major topic of discussion was the validity of wilderness as a land classification and expressions of frustration that "business as usual" could not prevail in wilderness. It has been a long time since I have heard those tunes. Acceptance of wilderness, commitment to its preservation, and serious concerns about how to manage it effectively are the rule at present wilderness workshops. And the general concepts listed above are widely understood by wilderness managers today.

CONCLUSIONS

The wilderness system is large and growing (fig. 1). There are many new wilderness managers as a result of additions to the system. In 1964, only 55 National Forests had any wilderness; now 128 do. Eighty-two percent of all National Forests have to face the challenge of managing wilderness. More national park, wildlife refuge, and BLM managers have wilderness responsibilities, and almost surely more will in the future. Many of the people now managing wilderness have no previous experience in this demanding type of management, and no training. Most wildernesses are totally unstudied, and

some whole types of wilderness and kinds of wilderness users are virtually unstudied; for example, desert wilderness, or snow-season visitors.

A strong knowledge base is essential to protect and manage the over 88 million acres of established wilderness. Society has a large investment in the wilderness system, and has forgone many other uses of the land. Will skilled professional management enable society to obtain a return, in the form of preservation of wilderness conditions and opportunities for high-quality wilderness experiences, that will make this large investment worthwhile? Can management provide adequate returns to society with the present level of knowledge? The research whose history has been reviewed can help. We have come a long way in research-based knowledge for wilderness management since the early 1960's. But there is a great deal left to learn. Furthermore, the management problems themselves evolve and change. Results of three surveys of wilderness managers over a 5-year period hint at such changes (Godin and Leonard 1979; Bury and Fish 1980; Washburne and Cole 1983).

Limited management budgets make it more critical that management be highly effective and sharply focused on important problems. This seems to require improved knowledge of wilderness resources, natural processes, visitor and external impacts, visitor desires and behavior, and the effect of management actions.

However, less wilderness research is being done now. Support has diminished for 5 or 6 years. Agency research and support for university and consultant research are down. New sources of support need to be developed. The Wilderness Research Foundation, which will be introduced at this conference today, may help fill this need. I hope so, but other funding sources will be essential.

There are barriers to wilderness research besides shrinking budgets. Most are not new, but some are becoming more serious. The Federal Paperwork Reduction Act, administered by the Office of Management and Budget, deals with the important problem of government reporting requirements that constitute a heavy burden for businesses and local governments. All collection of information by Federal Government employees or by anyone who is federally supported must be reviewed and approved by the Office of Management and Budget. Technical review of questionnaires and research design to assure quality control is certainly desirable. However, the application of lengthy, formal approval procedures to small-scale, voluntary questionnaires used in wilderness visitor studies impedes effective research in response to managers' needs. Planning lead time now exceeds 1 year as a result of requirements for advance listing in annual information collection budgets and the typical drawn-out process of review. Even the term "respondent burden" seems of questionable appropriateness for voluntary questionnaires. Many recent surveys have used mail questionnaires, and 80 to 90 percent rates of return are usual. Visitors are answering questions about something important to them, and most of them welcome the opportunity to express themselves. Seriously hampering research in order to protect people who seldom feel imposed upon seems unfortunate.

Some wildernesses have dropped permit requirements and others have abandoned trail registers. The reasons for these changes are unclear. Shrinking budgets, failure to use permit or register data effectively for management and thus assignment of low priority to collecting the data, and a desire to not obligate visitors unless truly necessary are all partial reasons for this retreat. These may be justified decisions, but they result in the loss of basic data on use and users that can impede both visitor and impact research.

Sometimes agency policies can make basic ecological research more difficult (Franklin, this proceedings) or hamper fire history research (Kilgore, this proceedings). It appears that less research is conducted in National Forest wilderness than in national park backcountry and wilderness (Butler and Roberts, this proceedings).

In this situation, I think there are five things members of the wilderness research community need to do:

1. Select high-priority problems to study. We will have to leave most problems unstudied, but clearly these should be problems of lesser importance.

As I have indicated earlier in the paper, I think wilderness managers will need more research on the impact process in a variety of settings. They need research on the effectiveness of various minimum impact practices in different situations. They need research to guide wilderness fire programs, especially manager-ignited fires. They need to have research finish the job of developing use measurement systems. They need help from research in applying the Limits of Acceptable Change system, and research to plug some remaining gaps (Lucas and Stankey 1985). Research needs to evaluate and develop nonregulatory visitor management techniques, especially education-persuasion. Trends need to be identified, including displacement of visitors by changing conditions. Finally, research needs to better cover the wide range of conditions and uses in the expanded wilderness system now established.

2. Do rigorous, high-quality research, to learn as much as possible from reduced amounts of research.

3. Collaborate and communicate with other researchers, with wilderness managers, and with concerned publics. This can help focus efforts on the most important issues and improve the quality of studies. It can also facilitate application of research to wilderness management. A good example of collaboration between university, Forest Service, and private consulting firm scientists, managers, and the public in the development of the Limits of Acceptable Change system and its application to the Bob Marshall Wilderness is described in this proceedings (McCool and others).

4. Strive for comparability and additivity to achieve a more integrated, cohesive research effort. I think at least one large, unified wilderness research program would facilitate integration, but if this fails to develop, scientists will need to work harder at cooperation. That, of course, is a major goal of this conference. If more studies could use common units of measure, comparable data classifications, and so on, one study could build on another more than has happened in the past. This could also facilitate study of trends.

5. Finally, strive for better days, so research can contribute to the management and preservation of wilderness. There is too much at stake for wilderness research to be neglected.

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THE WILDERNESS RESEARCH FOUNDATION

Glenn E. Haas and Michael J. Manfredo

ABSTRACT

The concept of a nonprofit, tax-exempt organization to support research related to the protection of our natural ecosystems was born in spring 1983. It was recognized that there was a lack of awareness, support, and coordination among individuals, institutions, and agencies involved in the scientific investigation of natural ecosystems. The Wilderness Research Foundation was created in response to this void.

The foundation was incorporated in the State of Colorado in May 1985 and formally introduced at the National Wilderness Research Conference on July 23, 1985. This paper describes the concept and direction of the foundation.

INTRODUCTION

The word "wilderness" was chosen as a generic concept which embraces all types of natural ecosystem land classification—national parks, national wildlife refuges, biosphere reserves, wilderness areas, and others. One commonality among these land classifications is the paradoxical question of how these areas can be managed unimpaired as naturally operating ecosystems while providing for their use and enjoyment by present and future generations.

There are a growing number of concerns to our societal goal of protecting natural ecosystems: visitor crowding; recreation use conflicts; disturbance and elimination of fish and wildlife species; deterioration of water quality; urban encroachment; air and noise pollution; and increasing consumptive demands. Public land managers, scientists, conservationists, artists, industrialists, politicians, and recreationists are beginning to recognize the complexity and challenge of this paradox. In response, under the corporate theme of "Learning to Preserve," the Wilderness Research Foundation has been established.

GOALS AND PROPOSED ACTIVITIES

The Wilderness Research Foundation will support wilderness through art, research, and information dissemination. It will serve to complement the activities of public land management agencies and conservation organizations in a nonpolitical and nonadversary role, without bias toward particular users or uses of wilderness.

Three foundation goals with associated activities are:

1. Increase the public's awareness of the importance of perpetuating an enduring resource of wilderness.
   a. Sponsor nationally prestigious wilderness art exhibits.
   b. Provide news releases to national media on the results of scientific studies.
2. Support high-quality research which will increase our ability to protect wilderness and its benefits for society.
   a. Obtain financial and in-kind resources for scientific research.
   b. Solicit research proposals and provide a rigorous peer review evaluation mechanism.
   c. Serve as a central administrative organization for multiorganization research and demonstration projects.
   d. Sponsor scientific studies and related activities such as think-tank retreats, development of interdisciplinary study plans, and demonstration projects.
3. Disseminate information among those involved in the protection of wilderness.
   a. Publish and distribute a periodic newsletter that would highlight foundation activities.
   b. Host workshops and short courses among public land management agencies and conservation organizations to facilitate information exchange.
   c. Publish and distribute a periodic monograph which focuses on critical issues (for example, water quality impacts, recreation carrying capacity, limits of acceptable change).

FOUNDATION DEVELOPMENT

The development of the Wilderness Research Foundation will occur in three phases. While the phases are sequential, various activities will occur throughout or be initiated as opportunities arise.

Phase I (Planning)

The first phase will occur over an 18- to 24-month timeframe and focus on: (1) developing a 5-year action plan; (2) developing a network of contacts among individuals, organizations, and agencies; (3) promoting the concept of "wilderness art" through a nationally prestigious annual wilderness art exhibit, (4) gaining media exposure of the theme "artists and scientists working together to preserve natural ecosystems"; (5) soliciting small financial and in-kind service contributions; and (6) submitting a 3-year seed grant proposal.

Phase II (Marketing)

The second phase will occur over a 36-month timeframe and focus on: (l) implementing a marketing and fund-raising campaign; (2) initiating several highly visible research and information dissemination projects; (3) continued promotion of the annual wilderness art exhibit; and (4) the establishment of an endowment fund.

Phase III (Implementation)

The third phase will begin in 1991, at which time the foundation will be self-sufficient and support activities based on available monies from its endowment fund. It is projected that 5 years of developmental planning and marketing activities will be necessary before the foundation will be in a position to fully implement its proposed activities. The amount and type of support for these activities will increase over time as efforts to expand the endowment fund are successful.

FOUNDATION ADMINISTRATION

The foundation's mailing address is P.O. Box 9502, Fort Collins, CO 80525. The foundation will be guided by a Board of Directors and an Honorary Board of Advisors, composed of scientists, conservationists, artists, land managers, business people, politicians, and others. Its directors as of July 23, 1985, are:

Dr. Glenn E. Haas
Foundation President
Associate Professor
College of Forestry and
Natural Resources
Colorado State University

Dr. Michael J. Manfredo
Assistant Professor
College of Forestry
Oregon State University

Mr. Leonard (Yank) Banowetz
General Counsel
Banowetz, Legget and Moore

Mr. Harry Crandell
Former Staff Director
Public Lands Subcommittee
U.S. House of Representatives

Dr. Jerry F. Franklin
Project Leader
Forest Ecology Research
USDA Forest Service

Mr. Curtis L. Gifford
Forestry and Agriculture Librarian
Colorado State University

Mr. Don Hatch, President
Hatch River Expeditions, Inc.

Ms. Joyce M. Kelly
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President's Commission on
Americans Outdoors

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Mr. Merrill Mehaffey, Artist

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RESEARCH AND MANAGEMENT: A TEAM FOR THE WILDERNESS

Robert A. Jantzen

We are here to address a subject of common interest—wilderness. Although united on that front, there are nearly as many perspectives of what constitutes a "wilderness," what the priorities should be for its use, and what the management and research needs are, as there are participants at this unique conference. The concept of "wilderness" certainly varies with the user. Managers also have wide-ranging philosophies regarding resource values of wilderness. For example, managers concerned with social and esthetic aspects of wilderness have different management and research needs than those charged with managing the resource as a functioning ecosystem for fish and wildlife populations.

In the U.S. Department of the Interior's Fish and Wildlife Service, the wilderness concept is broad, extending beyond those lands designated as wilderness by the law of the land. It certainly includes those designated lands, but it extends also to the management of species that may exist in a single, pristine desert spring and to those species that traverse the North American Continent in their annual journeys from the Arctic to the Gulf of Mexico. Our agency is oriented to both the land base and habitats, and to the species that live there.

MANAGEMENT RESPONSIBILITIES

For 15 years, starting just 6 years after the passage of the Wilderness Act, the Fish and Wildlife Service has been managing lands legally designated as wilderness areas or as wild and scenic rivers. These lands total over 19 million acres or one-fifth of our entire 90-million-acre National Wildlife Refuge System. The lands, located in 25 States, represent an array of arctic, desert, tropical, coastal, riverine, grassland, and forest ecosystems.

The Fish and Wildlife Service also has management responsibilities, under other legislative mandates, for species and their habitats that require wilderness or natural ecosystem settings. These mandates include the Endangered Species Act and the related coordination, consultation, listing and delisting, and recovery work. One of our oldest legislative directives outlines migratory bird responsibilities under international treaties. Through the Pittman-Robertson Wildlife Restoration Act, we work through some State programs to support wilderness-related research and management. The Marine Mammal Act expands our responsibilities beyond our shorelines. These and various other legal authorities present us with an ever-challenging role in the wilderness management arena.

As you might imagine, our management concerns as an agency are as varied as the natural resources we manage, the legal mandates that guide our activities, and the public interests in our programs. Research and development activities in the Service have traditionally been a key component in the management of fish and wildlife resources. The origins of this research go back to the Bureau of Biological Survey in the early 1900's and the Office of Economic Ornithology, created in 1885. Early investigations provided a solid foundation of facts for the emerging resource management profession, thus establishing a precedent. The Service has continued the commitment to a management and research partnership; even under current economic conditions, we maintain a personnel staffing ratio of approximately five managers to one research scientist. The research function in the Fish and Wildlife Service receives its direction from management. This ensures management involvement in setting priorities for research and utilization of new information. It also ensures that the research activities stay attuned to the ever emerging and changing management needs. It is through this partnership, or team approach, that the Fish and Wildlfe Service develops and implements its management strategies, including those related to wilderness.

RESEARCH ACTIVITIES

The Service has many research activities that relate to wilderness management needs. I have grouped them into eight basic categories.

1. **Endangered species.**—Our research efforts on endangered species have a common goal—to learn enough about each species' life history and its habitat requirements so that natural resource agencies can implement management resulting in the delisting of the species. Our Moapa dace studies in Nevada, for example, have determined that this fish is unique to hot springs "microwilderness" settings, and has specific requirements for water chemistry, spawning substrate, and water velocity at each life stage. This information is being used by the Moapa National Wildlife Refuge staff to provide suitable habitat that now supports a new, larger population of this species, a major step toward recovery.

In a second example, life history relationships are being unlocked on a remote Wyoming ranch where a remnant black-footed ferret population was discovered.

Presented by Richard N. Smith, Associate Director-Research and Development, Fish and Wildlife Service, U.S. Department of the Interior.

Again, management recommendations are coming directly from the cooperative Wyoming Fish and Wildlife Service research effort to management.

We have research efforts continuing on the mountain caribou of northern Idaho, on the tortoises of the southwestern deserts, the gray wolf, and grizzly bear. The wolf and grizzly have become, perhaps, almost the standard-bearers of many wilderness advocates.

As we continue to unravel the biological requirements of each of these species, in their respective ecosystems, we incorporate that knowledge into a fact-based recovery plan. We fully hope one day that the population and habitats of these and other species can be enhanced to the point where the endangered species designation can be removed.

2. **Marine mammals.**—The Fish and Wildlife Service has management responsibilities for three species of marine mammals—sea otter, walrus, and polar bear. All are of special concern because of their commercial value, their significance to native Americans, and their requirements for a relatively undisturbed lifestyle. Each species is susceptible to overexploitation because of the remote, relatively fragile ecosystem of which it is a part.

We have ongoing research on the sea otter on the West Coast, and on all three species in Alaska. Additional work is needed to answer the major management questions of population status and trends and impacts of development activities on reproduction, survival, distribution, and movements. Development of the logistics and techniques required to work on these far-ranging species in the Arctic is a challenge in itself. Again, our research efforts are keyed to achieving specific management goals.

3. **Salmon.**—The Pacific and Atlantic salmon may not be generally thought of as wilderness species, because many stocks are heavily subsidized by fish culture operations. However, a major need in Alaska, on the West Coast, and in the Northeast is to preserve and protect the remaining natural spawning runs of these valued species.

In Alaska and the Northwest, natural spawning runs often occur in wilderness regions. Management of the many salmon stocks requires a complex information base on genetics, disease pathways, habitat requirements, and life history. The Fish and Wildlife Service has laboratories in Alaska, Washington, and along the East Coast, all working cooperatively to support salmon stock management and the role wilderness areas play in this management.

4. **Waterfowl.**—Waterfowl nest throughout the vast wilderness breeding areas in the Canadian and Alaskan tundra and boreal forests. Duck brood production and specific habitat requirements of this valuable wildlife resource continue to be priority management concerns because of gas and oil and other developments throughout the sensitive environment in these northern regions.

I cannot stress enough the importance of an adequate information base to provide guidance on when, where, and how each development can occur without impacting ducks, geese, and other aquatic birds. Our research efforts in Alaskan wilderness are currently focused on North Slope and Yukon Delta goose breeding populations.

5. **Land use impacts.**—An essential activity of Service work involves coordination with other Federal agencies charged with management of water, timber, forage, and recreation resources. We provide a major part of the biological analysis and mitigation planning for fish and wildlife on federally funded projects.

Studies on the effects of logging activities on avian and herptofauna in the Pacific Northwest and the effects of grazing management systems on arid lands and natural riparian communities and wildlife species in National Wildlife Refuges are providing direct management guidelines. Forestry and livestock operations can be positive management tools for fish and wildlife, even in remote and "natural" ecosystems.

Our coastal ecosystem studies are providing unique guidance for regulatory agencies and industry throughout the Gulf Coast. For example, the Service's detailed mapping of colonial wading bird nesting habitats and the development of habitat models to identify their habitat requirements are now commonly used tools for screening development sites and for planning restoration efforts.

Resource development will continue to occur in what we now consider to be remote, pristine ecosystems. We must have the biological facts that are derived only through diligent, directed research thereby ensuring protection for the fragile parts of each ecosystem and providing management options for those parts of the ecosystems that can be compatible with development.

6. **Acid precipitation.**—The complex ecological relationships impacted by acid precipitation are slowly being unraveled by various research investigations. One fact is clear: aquatic habitats in many wilderness areas are being affected by acid precipitation. Even in well-buffered lakes, our scientists have found that water quality is being threatened by the increased phosphorus available in acid precipitation and subsequent stimulation of phytoplankton growth, and eutrophication or aging of the lakes.

The Service is involved both in basic research on the effects of increased acidity on fish and their food chains and on mitigation techniques. Our research efforts and a concurrent operational field evaluation program are monitored by a management coordination group—an excellent example of how managers and researchers combine forces to produce maximum return on dollars spent.

A few of the mitigation options currently being investigated are applying acid-neutralizing materials, creating favorable microhabitats for fishery resources, stimulation of biologically produced alkalinity, manipulating sediments, developing resistant fish strains, and fisheries management modifications. Through these coordinated research and management actions we hope to remedy the aquatic ecosystems already impacted and protect susceptible systems until acid-producing emissions are controlled.

7. **Technologies.**—Researchers often have to develop a technique or tool before they can carry out their investigations. Many of these research tools are incorporated

by managers in operational programs. The following are some examples of research and development techniques our scientists have developed that have application in wilderness management.

The Instream Flow Incremental Methodology (IFIM) is one such technique. Water is a precious commodity, especially in the Western United States. Also, many of the National Wildernesses, Wild and Scenic Rivers, National Parks, and National Wildlife Refuges are either the source of valuable water resources or are dependent upon the waters within their boundaries. I suggest that managers consider using this modeling approach to document natural flows in nondesignated wilderness streams on Federal and State lands near metropolitan areas before court action occurs to adjudicate the urban area's fair share of clean water. "Proactive" management of wilderness water resources should be a priority for wilderness managers.

A computer-based planning tool we developed is called MOSS, a geographic information system. It has been accepted by several resource management agencies and is currently being applied on wilderness lands. It is a map overlay and area-analysis software package to aid in master planning of large geographic areas and for conflict resolution. It is a powerful tool for those who handle complex and multilayered spatial or map-based data sets.

Technology developed for research but with application for management is a remote sensing system to monitor the far-ranging movements of the Porcupine caribou herd in Alaska and Canada. The system consists of advanced radio transmitters that transmit both biological and locational data through satellite-based receivers to a computer system. The impulses are reduced to meaningful information on location, distance, and time of movements. The activities of the animals at each location are then integrated by a geographic information system onto habitat maps, also obtained by satellite-based remote sensors. The technique can be applied to any detectable species that occurs in remote locations. Direct management decisions on where to allow roads or when to restrict human interactions can be based on this type of information. The technique does require committing considerable resources. But when one is entrusted with management of valuable commodities such as wilderness areas, the cost is reasonable.

8. **Information transfer.**—I have emphasized, for each of the categories of Fish and Wildlife Service Research and Development, how we integrate research findings with management. We are dedicated to making the results of the research work and the expertise we have available to all Service managers.

Information transfer has paid off in bringing our research and management people into an even closer working relationship.

I believe it is important to get research results into the users' hands, and that the researchers must make an extra effort to do so. Thus far, I have emphasized a commitment to and the occurrences of the management-research team, and the use of factual information as the basis for sound decisions. I would be less than candid if I said it always happens in our agency. At times, decisions are made without adequate information, and sometimes without information that is available. In our form of government, political decisions play a major role in some of our management actions. Also, some managers don't have the time, or take it, to use the information at hand. Still others try but cannot find the information in time or it's just not available. I contend that managers of wilderness resources cannot afford to overlook information or data about the values, status, etc., of the resource base. Once it's gone, a "wilderness" resource is costly, if not impossible, to restore.

On the other hand, researchers are partially responsible for any management-research gap. They need to remain attuned to the types of management decisions being made and the related information needs. They have to ensure that their studies do support and can be related back to the priority management questions. Researchers need to go out of their way to communicate their results in management terms.

RESEARCH PRINCIPLES

I'd like to close with some principles that apply to wilderness research that I think are important. First, a management-research team has to have a positive, cooperative, mutually supportive attitude. There needs to be an openness and willingness to share and explore ideas. Team members must be willing to change attitudes and perspectives when the management environment (goals and managers) changes and when new biological information becomes available.

Second, wilderness managers have to involve the researchers in the management process. Researchers have to get involved in management problems to help identify the key research (and researchable) issues. Managers should work with researchers and use various modeling approaches as planning tools to identify system relationships and priorities.

Third, managers must be willing to pay the price, financially and in time, that sound research requires. Advance planning and long-term research must be balanced with brushfire types of studies. Both are needed by managers; both have their advantages and costs.

A fourth principle is that researchers, even in wilderness settings, must make full use of controlled design experiments versus strictly observational, naturalist approaches. We must have more "cause-effect" studies that address clearly identified management questions. This is a more cost-effective means of addressing priority problems. This principle may cause some philosophical discomfort among some of those into the pursuit of knowledge for the sake of pure science. I am speaking as a public official who is committed to and supports a sound research program but one who frequently sees a strong need for a more scientific, quantitative approach to research studies.

Last, and perhaps the real "bottom line," is that managers must be willing to implement research findings. They must be willing to adapt their ways of doing

business, their decisions, to make full use of the technical knowledge available to them. Modern wilderness managers must be visionary, "proactive" decision makers, basing their actions on today's best biological knowledge but with an eye for the future.

With a solid team approach to wilderness research and management, I believe resource agencies can manage all sizes, shapes, and degrees of wilderness for the protection of the valuable resources associated with them, and the enjoyment of all those yet to come.

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MANAGING OUR WILDERNESS HERITAGE

Robert F. Burford

It is a great pleasure to be back in my home State of Colorado. I am proud that Colorado State University has taken the lead in organizing this conference. The Bureau of Land Management recognizes research as a vital tool in managing wilderness areas, and is appreciative of the opportunity to serve as a cosponsor of this conference.

Wilderness is an important part of America's heritage. Wilderness areas deserve the best care and the most thoughtful management we can give them. As Federal land managers, we tend to get caught up in the day-to-day considerations over which lands should be designated as wilderness, and which should continue to be managed for other values. Once the Congress has acted, however, and designated an area as part of the Wilderness Preservation System, it is time to unite in a consensus effort to manage these areas the best way we know how. If we succeed, today's wilderness values will be there for our children, and their childrens' children to enjoy.

During the past year, Congress designated the first large areas of BLM lands as part of the National Wilderness Preservation System. We now have 370,000 acres, in 23 different areas, spread over eight States. These areas contribute significantly to the diversity of the Nation's dedicated wilderness system.

BLM's 23 areas are just the beginning. Unlike the other three wilderness agencies, BLM received a wilderness mandate from Congress only 9 years ago, and we are still in the midst of our wilderness study program. The findings of those studies will be submitted to Congress over the next few years, and no doubt new BLM wilderness areas will follow.

FUTURE DIVERSITY

Judging by the lands under study—about 25 million acres—future BLM wilderness areas could be very diverse. The lands range from arid desert to whitewater rivers—from towering canyons to dry lakebeds—from sagebrush flats to mountain meadows. In fact, very few BLM areas resemble the classic Forest Service wilderness, with mountain peaks and glacial lakes. Many BLM wilderness areas will be drier and flatter.

It has been said that BLM lands are "the lands nobody wanted." We all know that is changing. From where I sit, they have become "the lands everybody wants."

Not only is there tremendous competition among the major users of the lands, ranging from mineral development to recreation, but there is also competition within each category of use.

This competition exists even among wilderness users themselves. In some areas, for example, we've even adopted measures to prevent recreational overuse. A case in point is the Aravaipa Canyon Wilderness in Arizona, where we have had a permit system in place for several years, limiting overnight visitors to 50 people per night.

In keeping with the Reagan Administration's policy against unnecessary and burdensome regulations, we would prefer to deal with such problems in other ways. Because people come to designated wilderness areas to escape the restrictions and regimentation of everyday life, we manage these areas to protect their unique values, in a manner least intrusive on their human benefactors.

This is one area where research can help.

We in the BLM have been attentive to the solid research already conducted by our sister agencies and the academic community. For example, our manual section on wilderness incorporates concepts that originated in Forest Service research efforts. We will continue this effort to profit by all research that we can apply to our on-the-ground management situation.

NEEDED RESEARCH

In addition, however, we will need research with a different emphasis. I will mention two examples.

In the arid climate of many BLM areas, impacts caused by recreational uses are slow to heal. So rehabilitation of overused campsites will be a real challenge. Another problem shows up in canyon country. Here, visitors are often concentrated into relatively small areas, and there doesn't appear to be much we can do to disperse this use. We are looking for some sophisticated thinking from the research community on problems such as these.

We also need help in the areas of insect infestations, management and rehabilitation of burned areas, and problems of wildlife management, both in and adjacent to wilderness areas.

As a newcomer to wilderness management, BLM is open to adopting the most innovative approaches to wilderness management. We are therefore in a position to apply new research findings immediately.

As each BLM wilderness is designated, our field offices will begin to develop a wilderness management plan for each individual area. These plans will offer our first opportunity to address the issues and problems specific to the area. We will attempt to incorporate good research findings, new ideas, and innovative solutions into our planning.

We already have a highly professional cadre of wilderness specialists on the job. Most of them have worked on the wilderness studies, and we are now utilizing these professionals for wilderness management activities, as we enter that phase of the program. We are also encouraging all of our wilderness managers to keep in touch with the research community, and to keep up to date on the latest research results. Some of our managers are attending this conference, and we will disseminate the conference proceedings widely among BLM field officials.

By the same token, I urge you who are doing research to keep the BLM in mind. BLM wilderness areas will present some challenging new problems that deserve—and will benefit from—your attention. I invite you to keep in touch with BLM wilderness managers, who can suggest specific research topics.

If you need somebody to put you in touch with the most appropriate field people, please call or write to our Branch of Wilderness Resources in our Washington office. David Porter, who heads that office, is here at the conference, and he will participate in the panel discussion this Friday.

The BLM has a very small appropriated budget to support all the wilderness research we need. Given the desire to reduce budget deficits, I do not foresee any significant increase in the next 2 years. So we are dependent upon your institutions and your ingenuity for conducting the needed research projects. As you discuss research needs with our field offices, however, they may be able to assist you in a variety of ways.

SETTING PRIORITIES

For the past 4 years I have spent much of my time as Director dealing with budget matters, trying to make sure BLM is appropriated the money it needs to take care of the public lands. The competition for funds is intense, both among the programs within BLM, and among the various parts of the Federal Government. And it's not going to get any easier. We must ensure that research projects are cost effective and make the largest contribution possible to improving management of these areas.

When thinking of wilderness research across the board, we really cannot afford to spend research money on projects of only passing interest. We could do a host of ad hoc projects that help individual areas, and yet totally miss the big picture.

The challenge is to focus on that big picture—and to develop a systematic action plan for wilderness research over the next 10 years. I am confident that if the ideas discussed at this conference are pulled together by a follow-up task force, you could come up with a 10-year action plan that would point the way toward research that is cost effective and gives us the answers we need.

We are fortunate to be the stewards of the National Wilderness Preservation System. We follow in the footsteps of others who conceived the wilderness idea, and we will be followed by other generations of stewards. If we do our job right, wilderness areas will be handed to the next generation in as good condition or better than we found them. Wilderness research is helping us in many ways to do that. I salute your efforts. And I look forward to your future successes in helping us to preserve our wilderness heritage.

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WILDERNESS RESEARCH: AN IMPORTANT LINK TO WILDERNESS MANAGEMENT

R. Max Peterson

This conference is very important to me, because managing wilderness is a vital part of the Forest Service's multiple-use mission. The Forest Service's interest in, and support of, wilderness has a long, proud history, and that interest both includes and is built on wilderness research. We have happily endorsed the new Wilderness Research Foundation and view it as a major, positive happening.

We are pleased with the addition of more than 6½ million acres of wilderness to the National Forest System over the last few years. The new additions doubled the number of designated National Forest Wildernesses and extended wilderness management responsibility to 92 percent of our Forest Supervisors. Of the 122 National Forests, 112 now have at least one wilderness. So we are strong supporters of wilderness. We believe in wilderness and its value to the American people and to the world in general.

A CHANGING FOCUS

The issues of how much wilderness is good and desirable and what areas should be given wilderness designation will never completely be resolved. However, we believe the forest land management planning process, in coordination with the legislative process, is the appropriate place to resolve the remaining quantitative questions of wilderness. We must now focus more attention on qualitative issues of wilderness management.

As was so aptly stated in the theme of the 1983 National Wilderness Management Workshop in Idaho, we must direct our energy toward "taking care of what we've got."

My challenge to the managers and researchers in the Forest Service is, now that we are stewards of more than 32 million acres of wilderness, what do we do to gain the most public benefits from this enduring resource of wilderness?

Last December at a meeting marking the 20th anniversary of the Wilderness Act, I stated some wilderness management principles that guide us, and I'd like to briefly restate them for you.

These wilderness management principles are grounded in the Wilderness Act, and direct that we should:

- Allow natural processes to operate freely;
- Maintain outstanding opportunities for solitude;
- Do necessary management work in wilderness without motorized equipment or mechanical transport whenever possible;
- Gather scientific information without the intrusion of permanent improvements or motorized equipment; and
- Manage special exceptions provided in wilderness bills for individual areas, while protecting wilderness values and keeping the 1964 Act as our basic guide.

However, as much as we talk about managing wilderness, our primary task is really to manage people who use wilderness, including our employees.

A key to properly managing people is to help them become knowledgeable about wilderness. This education element was an important theme at the 1983 Wilderness Management Workshop. A steering committee formed from that conference, and chaired by Dr. Edwin Krumpe, has recently released an excellent 5-year action program for improving wilderness management. Ed will present a report on the action program later today.

The steering committee's action plan does an excellent job of providing a sense of direction. Now it's up to all of us to start moving purposefully in that direction. Now that we've got a framework, we must continue building a sound wilderness management program. Wilderness research is an important element in our efforts.

RESEARCH RELATIVELY NEW

Wilderness research, both basic and applied, is a relatively new area. However, we've accumulated centuries of combined experience in wilderness management since the Forest Service established the first Wilderness Area on the Gila National Forest more than 60 years ago. A worthwhile, short-term research project would be to capture the knowledge that has come from this experience. Let's not lose it!

One of the reasons we need research in wilderness is to help us better understand this resource. Two of the key concepts stated in the Wilderness Act are that wilderness is ". . . an area where the earth and its community of life are untrammeled by man . . ." and which ". . . has outstanding opportunities for solitude or a primitive and unconfined type of recreation." There are basic questions we must ask. What makes a particular ecosystem operate? What are the area's natural processes, and what effect do human and uncontrolled natural forces have?

Presented by Roy Feuchter, Director, Recreation Management Staff, Forest Service, U.S. Department of Agriculture, Washington, DC.

What are the effects of human interaction on the natural processes, and how severe are they? What effects do pollution sources from outside the wilderness have on the air, water, and vegetation within the wilderness?

But perhaps even more basic, or at least of potentially more impact, is the question of how do we build a wilderness ethic or nurture that which exists? What are the most efffective education techniques? Where and when should we direct our communication? How do we structure our message that wilderness is more than simply recreation in a primitive environment? It is important as a resource! It is needed as a resource! It should not be used to prevent something else. I don't know if research can help us clarify this distinction, but I do know they must not add to the problem; and I suggest we all need to review our motives in this regard.

Perhaps the toughest question of all, because it may be the key to maintaining wilderness in the future, is how do we manage, without destroying, the unmanaged experience that is fundamental to all wilderness? Our agency intention is to manage wilderness, to continue to improve our management, and to sponsor and conduct research to that end.

GOAL IS QUALITY

Our goal is to maintain the quality of wilderness and to provide an "enduring resource of wilderness." We fully expect this will require constraints, limits, and restrictions, and that some of those restrictions will conflict with either existing activities or future activities that may in themselves be valid, and either useful or needed endeavors. Some may be strongly in the public's interest but may lose out to the national need to protect and maintain wilderness.

It is our intention that wilderness management will not be "business as usual." We will strive for purity—in the short run, as much as reasonably possible, and in the long run, always! This will not be without heartache. In fact, there may often be weeping and wailing and gnashing of teeth as special interests see their "ox being gored." To some extent there are no easy answers, and there will be some points we lose in the political halls. That is part of our political system, as long as professionals provide their proper input.

But there is also the potential and opportunity to ease much of the pain, resolve problems, and lessen impacts partly through intelligent, common-sense management, and partly through research that sets out to help solve management problems.

Conferences like this can help identify those problems and research needs. An example is the need to provide the social research background for that problem I call the toughest of all: How will we regulate, limit, and restrict without stealing the feeling of freedom and unconstrained adventure from the wilderness use?

Wilderness managers should work very closely with scientists to recommend and develop research programs so that we do not waste precious research time and dollars on efforts that are not top priority or related thereto. A good example of excellent teamwork between Forest Service wilderness researchers and managers is the development and testing of the Limits of Acceptable Change concept. This concept is currently being tested in several wildernesses throughout the National Forest System. I believe it can help us maintain the quality of wilderness, and it's an especially important concept for the management of the recreation resource within wilderness.

We must be careful, though, that it is well understood and applied correctly. It must not be used to simply zone wilderness so that lower standards can be justified for some areas. Nor must it be used to allow uncontrolled increases in wilderness use or degradation in the name of special conditions or problems. Rather, it should be a technique that recognizes special conditions and helps us maintain a high quality of wilderness, even when conditions vary within a given area.

There is no doubt that when people visit wilderness some changes must occur. However, we must adapt or limit the change to meet our responsibility of maintaining the wilderness character. The pressure will always be on the managers to allow more use or to accept something "less natural." Perhaps a better name for the wilderness management concept would be "Acceptable Limits on Change Imposed by Wilderness!"

ACT LEADS WAY

Managers must be diligent in setting standards so we can be sure we comply with the Wilderness Act. The Act directs that our management of areas ". . . leave them unimpaired for the future use and enjoyment as wilderness, and . . . provide for the protection of these areas, the preservation of their wilderness character . . . ."

Researchers, when planning research within a wilderness, are presented a special challenge by the Wilderness Act. The gathering of information about resources within wilderness must be done ". . . in a manner compatible with the preservation of the wilderness environment."

This means that unless justified ". . . to meet minimum requirements for the administration of the area . . ." data must be gathered without permanent structures or the use of motorized equipment and without intruding on the visitors' solitude. This makes the researchers' tasks more difficult, as it does managers', but neither management nor research can afford to violate wilderness.

It's a big task—worthy of our best effort—because the benefits of an "enduring resource of wilderness" are even bigger than the task!

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THE NATIONAL PARK SYSTEM: THE CHALLENGE AHEAD

William Penn Mott, Jr.

It is a pleasure to appear before you today to discuss a topic very dear to me—the future of the National Park System. As you well know, I came to the office of Director of the National Park Service with a very definite vision of where I believe the future of the National Park Service lies, and I am delighted to see this very issue discussed in many corners of our society, and those of other nations.

These discussions are now beginning to converge, to come into focus, as is evidenced by the efforts of the Conservation Foundation in their recent publication, "National Parks for a New Generation: Visions, Realities, Prospects," the International Union for the Conservation of Nature and Natural Resources (IUCN) as they develop and test their computer system to establish and monitor the status of parks and protected areas worldwide, and Secretary Hodel's new initiative to increase public awareness and involvement with all publicly owned land resources. It is this type of creative thinking that will be of great help as we open up a dialogue and draw on the creative energies and problem-solving approaches of all constituencies, at the local, State, national, and international levels, to chart our course carefully for the future.

While the National Park Service has served this Nation's conservation community well since the establishment of Yellowstone National Park in 1872, the Service has also shared with other nations the value of parks and protected areas. In fact, through the International Parks Seminar, we have trained a large majority of the current directors of various park systems throughout the world. In the past, we have clearly demonstrated leadership, and it is my intention that the National Park Service will, as we chart our course for the future, lead the way toward a greater understanding of such critical issues as the role of parks and protected areas in the fields of biological diversity, integrated regional and ecosystems planning, the systems approach to park management based on an adequate data base and understanding of the resources under our stewardship, and the evolution and survival of our cultures. We intend to provide positive, direct, and creative leadership to speak to issues and set standards of administration and maintenance for others to follow.

Critical to the dialogue that we are opening up is an ongoing discussion with Members of Congress. Not only does each Congressman impact policy as various legislative issues are deliberated, but it is the Congress that considers our budget requests, which directly influences policy. When we consider some budgets of other Federal bureaus, the National Park Service budget seems small; but the job it does, from a quality of life point of view, is quite large. In fact, I view it as an investment in our future, the future of our children, our grandchildren, and our great-grandchildren.

BROAD OBJECTIVES

As we begin to chart our course for the future, I believe that we need to look objectively at the state of the National Park System today with its 337 units and 79.5 million acres of land visited by 350 million, one-third of a billion, people annually. We must decide what actions should be taken to preserve this legacy for future generations.

In that light, we must seriously begin to think about the relationship of Federal agencies with each other so that one agency does not take action that will harm the efforts and mission of another and that systems at the Federal, State, and local levels relate to each other harmoniously. I believe sincerely that a united, working-together, interrelated system can meet the ever-increasing demands of the visiting public without serious damage to the natural and cultural values of park systems everywhere.

We also need to be able to forecast and forestall those technological and environmental changes that could result in irreparable damage to the natural and cultural resources that are entrusted to our stewardship. Further, we in the National Park Service need to rededicate ourselves to serving the millions of visitors who come to our National Parks so that they can enjoy, appreciate, and take pride in our national heritage under quality conditions and through a professionally established and well-trained group of interpreters with skills to bridge the gap between the urban culture of our society and the natural world.

THE 12-POINT PLAN

To more carefully define these broad objectives, I have developed a 12-point plan that I believe is crucial to our future. I have developed these 12 points from my 50 years of experience as a practicing park professional and in consultation with the 10 regional offices of the National Park Service and the directorate in the Washington office. In fact, I discussed these specific points with Secretary Hodel as a basic condition of my acceptance of the position of Director of the National Park Service; and he has given me his full support.

At a meeting with the regional directors and constituency groups at Yellowstone National Park in June of this year, I shared these ideas. At that time, I

challenged the regional directors and service center managers to begin making opportunities out of what may be perceived as "problems." This is one of my personal philosophies in life that has stood me well, and I intend to encourage this philosophy during my tenure as Director of the National Park Service.

In my challenge to the regional directors and service center managers, I specifically asked that each one of them become personally involved in these 12 points by each selecting one point, approaching the issue creatively, and developing an implementation plan. My 12-point plan has now been published in booklet form and the implementation process now begins. Because I need the awareness and support of organizations such as this group, I would like to take this opportunity to share with you the highlights of my 12-point plan.

1. Develop a long-range plan or strategy to better protect our natural, cultural, and recreational resources. It is absolutely essential for us to develop broad, new concepts for better protection of our resources over the next 50 to 100 years. The directions that we gain from these concepts should ultimately be viewed as the "hallmark" of contemporary thought concerning resource protection. It should be the very best that we can do. I expect us to involve the best "minds," both within the Service and outside, to produce, in a highly professional manner, the concepts that will give focus to our management decisions and provide guidance for expanding our research efforts to meet critical needs.

2. Pursue a creative, expanded land-protection initiative. Additional lands must be made available to meet public demands and round out the system for increased use and for the protection of this Country's natural and cultural heritage. Some of this acquisition must be met through fee acquisition. However, I do feel that we have not used other innovative acquisition strategies involving States, other Federal agencies, and the private sector as extensively as we might. Changing economic conditions indicate that we must expand these avenues not only because of the limited funding we face, but because, frankly, these other not-for-fee acquisition possibilities offer us some real opportunities and challenges to provide for the public and the resources. This flexibility also could offer additional acreage without large expenditures of money.

We need to change our approach and attitude toward land acquisition strategies. To understand these new techniques, it may be desirable to have a workshop as well as training opportunities or personnel exchanges not only to review the diversity of land protection strategies, but also how best to manage such lands. We need also to revalidate our ideas.

3. Stimulate our interpretive and visitor services responsibilities for greater public impact. For too long, we have not realized the power of interpretation in helping us achieve the mission of the Service. Every point of public contact represents a tremendous opportunity for us to build public support for the National Park System and to educate our now-predominantly urban population on the natural and cultural values found in the National Park System, and also how the public can best appreciate these priceless assets and protect them for future generations to enjoy.

I feel we must emphasize the broader context within which the units of the National Park System are managed. We must "weave" into this a focus of understanding how parks contribute to the quality of life and productivity in our country and throughout the world. Interpretation and visitor service functions must be "infused" with new ideas and a broader vision of parks.

4. Effectively share our understanding of critical resource issues with our publics. Obviously, we don't know all the answers to solve the critical resource issues we face, but we have an obligation to share what we do know. On many complex issues, such as historic preservation, acid deposition, critical habitat loss, and endangered species management, we can present these concerns in a context of public understanding. A public that understands, and shares its understanding with our elected officials at all levels, is a very powerful force.

5. Increase public understanding of the role and function of the National Park Service. We must communicate more effectively and more frequently with the public exactly what we are planning to do as well as what we have accomplished. At the park level, we must involve the local communities in what we are doing and how it relates to them. Perhaps a public statement at the beginning of each year that defines what we hope to accomplish for the year would be a good first step.

At the Washington level, I expect to present to the Administration and to the Congress an annual report. This will summarize the work and accomplishments of the Service during the year, together with a statement of our fiscal accountability.

I would also like to let you know that I will encourage each superintendent to provide me with a one-page report every 6 months on what is taking place in that park unit. I plan to transmit these reports to Members of Congress who have units of the National Park System in their districts.

6. Expand the role and involvement of citizen groups at all levels in the National Park Service. In my experience, some of the best ideas and most stimulating thoughts for improved management and development of parks have come from an interested and involved public. We need these groups and individuals to be involved in meaningful ways. They tend to recognize problems as opportunities. They see the world from a different perspective. In an era of accountability, the close involvement of citizen groups to provide constructive criticism, support, and a different way of thinking can be invaluable.

7. Seek a better balance between people management and resource management. We have areas, in my judgment, that may be out of balance. It seems we unintentionally ignore the public in some areas and we err in others by ignoring the resource. I feel this lack of balance often creates issues that put the Service in adversary roles with some of the public. In carrying this out, I will review closely our management philosophies for

balance, visitor use, and resource protection, and the guiding research which provides the information needed to determine that balance.

8. Enhance our ability to meet the diverse uses that the public expects of the National Park System. Obviously, we cannot and should not provide for every use or activity that the public would like to have in every unit of the National Park System; but, my question is, "Are we being as flexible as we can, consistent with legislation?" If we are already as flexible as we should be, then we may need closer involvement with others—States, Federal agencies, and the private sector—to provide some of the activities expected of us. By working with the park systems at the State and local levels, we will be able to identify where the most appropriate activity can be found; and, again, we need to let the public know where they can be served, rather than telling them "no."

9. Expand career opportunities for all employees. In my judgment, the success that has been enjoyed by the National Park Service rests with the trust and respect that the American public has for the competent, dedicated employees of the Service. Everything we hope to do must foster this tradition of obtaining and keeping a productive workforce.

We must ensure that our most capable employees are placed in the most demanding, challenging opportunities that the Service can offer. We must constantly seek new ways to challenge our employees to achieve excellence. And we must develop new ideas that will provide for career enhancement. I know that there has been some excellent work done on this important subject, and I intend to build on that.

10. Provide for appropriate planning, design, and maintenance of park facilities. Over the past 5 years, the National Park Service has made inroads, with Administration and Congressional support, into bringing park facilities up to standards that visitors and employees have a right to expect. With the progress that has been made, comprehensive preventive maintenance becomes an essential, continuing element in our management program. We will use the latest appropriate technology as well as a "creative systems" approach to accomplish this important task effectively and efficiently. It represents 45 percent of our total operating budget in fiscal year 1985. Planning must meet the needs of the public and management simply and in harmony with the resources of the area. Costly, overdesigned buildings must not be allowed. This does not, however, mean that quality in construction will be sacrificed. To the contrary, we will constantly strive for quality not only in our planning and construction but, also, in our management and maintenance of the units of the National Park System.

11. Develop a team relationship between concessioners and the Service. I would like to develop a more cooperative relationship between the Service and the concessioners so that they become a part of the team. We want their operations to reflect the same quality and attention to the public's needs as is demonstrated by the Service itself.

12. Foster and encourage more creativity in the management, administration, and communication of the National Park Service. Any organization that hopes to be successful during the rapid changes we face today must be extremely creative in the way it views its mission and in the way it carries out its responsibilities. The freedom to take "calculated risks" must be one of our guiding principles. We must evaluate all ideas, both old and new, for appropriateness to the situation we face. I will initiate actions to make an overall assessment of this bureau's capability to carry out this mission creatively and with the flexibility that today's changes require.

FUTURE IS BRIGHT

These are the key points that I believe are critical to the future of the National Park System. In the past, the National Park Service has met its challenges with direction and commitment. However, times are changing rapidly, and with these changes we need to sharpen our skills, dedication, and ability to meet the complexities of the future. With your help, along with that of our other constituencies and our public, I firmly believe the future is bright and that we can pass on to future generations for their enjoyment and use a National Park System unimpaired.

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SCIENTIFIC USE OF WILDERNESS

Jerry F. Franklin

ABSTRACT

Relatively little scientific use has been made of wilderness areas despite the outstanding opportunities they provide for research. Examples are given of the applicability of wilderness-based research to solution of problems outside wilderness areas, such as those on commodity lands. Deterrents to research include attitudes of scientists and managers, restrictions on equipment and sampling techniques, and conflicting human activities. Suggestions are made for increasing the level of wilderness research.

INTRODUCTION

Science has been used as a justification for protecting wilderness areas since the beginning of the wilderness concept. Proponents have emphasized the value of such natural areas for baselines; that is, to provide for comparisons with managed landscapes, for studying ecological processes, and for preserving gene pools. The interaction of science and wilderness has scarcely gone beyond the rhetoric and printed texts, however. Very little scientific use has actually occurred, and even less consideration has been given to scientific values in management planning, programs, and developing wilderness regulations.

Increased scientific use of wilderness is needed to demonstrate its important potential value to society as well as the contribution that science can make to wilderness. The current low scientific use clearly makes less credible this major justification for the wilderness system. Lack of research also reduces the amount of scientific information available for identifying and solving management problems.

In this paper the potential of wilderness for science is reconsidered and examples of the relevance of wilderness-based information to intensively managed landscapes are provided. Problems contributing to the low scientific use of wilderness, including conflicting uses and regulations, are also considered. Some steps are suggested that could help nurture science within wilderness areas. My intention is to stimulate the extensive collaboration between wilderness managers, users, and scientists that will be necessary for society to extract the priceless information contained in our wilderness system.

ECOLOGICAL PROCESSES IN WILDERNESS ECOSYSTEMS

Fundamentally, wilderness ecosystems are just like other ecosystems in their basic attributes of structure, function, and process. There are cycles of water and of nutrients, just as in nonwilderness ecosystems. Productivity occurs as energy from the Sun is captured through photosynthesis and converted to organic materials. Organic materials are ultimately decomposed in a multitude of detrital pathways.

Within wilderness ecosystems are patterns of disturbance and recovery, equilibrium not being a normal natural condition. Primary succession or ecosystem development occurs, as on recently bared deposits of glacial till. Complex patterns of secondary succession develop after traditional disturbances, such as the wildfires that so many wilderness ecosystems have adapted to, or powerful, large-scale disruptions, such as those associated with volcanic eruptions.

Wilderness ecosystems are sites for an array of ecological interactions, as are all ecosystems. They provide habitat for a variety of organisms and sites for complex animal and habitat interactions. Interfaces, sites of material transfers, occur between terrestrial and aquatic ecosystems. Wilderness ecosystems are, thus, essentially the same as any other ecosystem in the structures, functions, and processes that are represented. The uniqueness of wilderness ecosystems comes from other attributes.

UNIQUENESS OF WILDERNESS ECOSYSTEMS

Wilderness ecosystems are unique in their scale and in their degree of naturalness, which provide people with unique opportunities to learn.

Scale refers to the occurrence of large areas with a high degree of integrity and continuity within wilderness. But wilderness landscapes can also have a high degree of complexity or diversity. The grand scale and complexity provide unique research opportunities (Franklin 1981). For example, we can study undisturbed aquatic and wetland ecosystems at the geographic scale of an entire river drainage. Interactions between biologic and geomorphic processes can be examined, as in relations between forest conditions and fluvial processes (for example, erosion and flooding). Investigations of animal populations, including large herbivores and wide-ranging predators (for example, elk [*Cervus elaphus*] and cougar [*Felis concolor*]) are possible. Wilderness landscapes allow us to look at patterns of diversity in composition and structure and to see how these are related to environmental factors and disturbances; examples are the size and shape of natural patches and the forms of boundaries or ecotones between patches that result from natural fire.

Naturalness, the second distinguishing feature of wilderness, refers to relative freedom from human and other external influences. It reflects "wildness," an attribute that makes the areas valuable as natural baselines. This fact was noted by Stanley Cain many years ago: "Wilderness areas are the only yardsticks we have—or can have—of the long-continued interactions of natural ecological laws. . ." (Sierra Club 1964). This is why wilderness areas are sought today as sites for studies of global background levels of pollutants, CO_2, and other substances. The initial study sites in the United Nations Environmental Programs's Global Environmental Monitoring System (GEMS)

are, for example, in the wildernesses of Olympic National Park (Washington State) and Torres del Paine National Park (Chile). An important aspect of the naturalness in wilderness is that it refers to processes currently under way as well as to historic impacts; hence the value of wilderness in monitoring programs.

Scale and naturalness are central to the outstanding value of wilderness for society generally and science specifically.

WILDERNESS AS A SOURCE OF INFORMATION

It is my view that wilderness has two primary values to humanity: information and inspiration. Philosophically, it can be argued that these are one and the same; however, I want to single out wilderness as a source of information—information that takes many forms. There is the genetic information encoded within species; wilderness areas contain some of the few remaining, large, natural gene pools of organisms. Historical information is contained in individual organisms, such as the tree-ring chronologies of the bristlecone pines (*Pinus aristata*). There is information on community processes, such as patterns and rates of tree mortality. And there is information on landscape-level processes, such as effects of fire and windstorms, which are often periodic and large-scale phenomena.

I want to emphasize that I am talking about information of broad value in our lives and activities **outside** the wilderness, although such information is almost always of interest and even of practical use to the wilderness manager. I am not talking primarily about research and information needed for management of the wilderness, which is an important but separate and less cosmic issue.

Examples are numerous of applying information from natural ecosystems to important problems or to resolving resource management issues in managed ecosystems. One of my favorite examples is the lesson that old-growth forests have taught about the importance of the dead tree both in its standing form (as a snag) and as a downed log (Franklin and others 1981; Maser and Trappe 1984). These dead structures serve many functions in both aquatic and terrestrial environments; they are a source of energy and nutrients, wildlife habitat, and, in streams, provide physical stability (Harmon and others 1986).

An ecosystem study on the South Fork of the Hoh River in Olympic National Park provides other illustrations of the relevance of the information in wilderness to managed ecosystems (Starkey and others 1982). The park area was selected because it had an ecosystem appropriate for the study, an undisturbed coastal valley, and park managers who strongly supported the project. The project was an intense, short-term interdisciplinary study ("pulse") that looked at relationships among geomorphic processes, landforms, alluvial forests, aquatic (especially fish) productivity, and elk. The research included many components and yielded many individual findings, such as the importance of down logs as nurseries for regenerating trees in the coastal forests.

Observations of various aquatic habitats for total biologic and fish productivity, including factors involved in habitat creation and maintenance, provided significant information applicable to managed landscapes outside wilderness areas (Starkey and others 1982). Major forest influences on fluvial processes and landforms were evident in the South Fork. Bank cutting on the higher terraces produced accumulations of woody debris and formation of river bars downstream. Particularly notable were occasional accumulations of woody debris that blocked channel segments. This process resulted in formation of off-channel habitat, one of four major aquatic habitats in the South Fork; the other three are main channel, valley-wall tributary, and terrace tributary habitats. The off-channel habitat was isolated from the turbulent and sediment-filled water of the main channel and provided aquatic organisms with clean, quiet water, good protective cover, and rich food sources. Off-channel habitat was overwhelmingly important in fish production and also functioned as a biological hotspot for the drainage system as a whole and as a refuge for main-channel organisms. Management prescriptions and State regulations for commercial forest lands outside Olympic National Park had concerned primarily main channels and largely ignored off-channel habitats. Perspectives were altered by this wilderness research, changes in attitude of critical importance in this region where anadromous fisheries and timber harvest are prominent. The South Fork study also provided a standard for sediment levels tolerable to salmonids.

There are other good examples of research in wilderness that are important in understanding basic ecological processes and developing management strategies. Long-term studies have been conducted of interactions between populations of gray wolf (*Canis lupus*) and their prey, particularly moose (*Alces alces*), in Isle Royale National Park (Michigan), the Boundary Waters Canoe Area (Minnesota), and Algonquin Provincial Park (Canada). These studies have drastically modified perspectives on the supposed balance between predator and prey populations and provided information necessary for managing an endangered species. Studies of fire history have been conducted in many wilderness areas, including the Boundary Waters Canoe Area and Selway-Bitterroot Wilderness (Montana), studies which would probably not otherwise have been possible. This research has provided essential information on natural fire regimes and helped alter attitudes from fire control to fire management, both inside and outside wilderness areas.

Hence, information from the wilderness, extracted through scientific research, has direct relevance to managed landscapes. It is also of value to the wilderness manager and builds the total information base for the wilderness area. Wilderness is also the source of as yet unasked questions—and their answers.

PROBLEMS IN EXTRACTING THE INFORMATION RESOURCE

Scientific research is the usual method by which we extract information from a source; unfortunately, we scientists and managers have made a poor start in extracting information from wilderness. Some positive examples are appearing for individual wilderness areas, but the general record of research use is abominable.

The low level at which the wilderness information resource is used is not because of unrecognized potential. The Wilderness Act (Sec. 4(b)) (The Wilderness Society 1984) gives equal weight to the scientific and recreational values of wilderness: "Wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use." Science in wilderness has been talked about for a long time; an early wilderness conference dealt exclusively with the scientific values of wilderness (Sierra Club 1964). But the promise remains mostly talk.

Perhaps part of the problem has been the lack of a strong advocate for the science resource. Much of the Wilderness constituency does not understand the importance of the opportunities. The Wilderness Act Handbook (The Wilderness Society 1984) has extensive material on Congressional clarifications of the original intent of the Wilderness Act and is useful in examining this issue. It is clear in the handbook that treatment of most resources—fish and wildlife, minerals, grazing, and so on—is either dealt with in the Act or has subsequently been clarified. All uses, that is, except for science. The use of the information resource has not been subject to further Congressional consideration. The reason is clear—the issue has not been raised; the scientific resource has no constituency.

Several issues or problems have deterred scientific use. These problems can be categorized as attitudinal, regulatory (mostly logistical), and conflicting use. Significant differences do exist among agencies, regions, and even individual wilderness areas in the intensity of these problems, just like the differences in the current level of scientific research. These differences are expected, given four agencies operating under four sets of regulations based on four laws (1965 Wilderness Act, Eastern Wilderness Act, Endangered American Wilderness Act, and Federal Land Policy and Management Act of 1976) (The Wilderness Society 1984). Agency differences clearly affect both the amount and type of research that goes on within wilderness areas (Butler and Roberts 1986).

Scientists themselves contribute to the attitudinal problems. They are often uninformed about regulations and unwilling to make necessary compromises to conform with wilderness values. Scientists can be arrogant and cryptic in their relations with managers and unappreciative of managers' problems. Some may feel that research gives them a license to do whatever they please. Scientists are, on the other hand, almost always short of the resources they need to carry on their research programs.

Managerial and user attitudes toward research in wilderness also are problems. These attitudes, which may include hostility and disinterest, apparently reflect a lack of appreciation of the potential value of scientific study. Some managers want only research that is clearly relevant to their immediate management problems. The Forest Service manual currently directs that if research can be done elsewhere, outside the wilderness, it should not be allowed within the wilderness; such direction (to do it elsewhere if possible) is not applied to any other use of wilderness which would otherwise conform with Congressional directives. New policy direction (approved but not yet published) is more positive; its objectives are to provide appropriate opportunity for scientific studies dependent on a wilderness environment and to encourage research in wilderness that preserves the wilderness character of the area.

Some attitudinal problems may result from poor education of managers on the importance of scientific use of wilderness and how research can benefit the preservation of wilderness in the long run.

Problems related to agency regulations (and their interpretation) include access, research methods, and instrumentation. Many wildernesses are rugged, and sampling sites may be remote. The long travel times may be a direct problem in processing chemical or other samples. A further complication may be the need for frequent sampling. Bulky or heavy equipment not suitable for ground transport by people or pack animals may be required to accomplish research objectives. Helicopter or other motorized access may be the only way to move such equipment or the way that has the least impact on wilderness ecosystems.

Research methods are another area of conflict. Although a lot of useful research can be accomplished with equipment no more complicated than a pad of paper, pencil, and measuring tape, much ecological research requires complex instrumentation. Some of this is electronic equipment that may, in turn, require a power source. Various kinds of temporary installations—instrument shelters, stream gauging stations, and exclosures—may be needed for specific research projects. Field markings, such as stakes for permanent plot boundaries, are often critical to ensure relocating study areas.

The third major problem is conflicting human activities. There are major differences among agencies in the seriousness of this problem. National Park Service wilderness areas are generally of higher value for ecological research than wilderness areas administered by other agencies because most conflicting human uses are absent.

Remember that naturalness is one of the chief reasons for the value of wilderness to science and society. But conflicting human activities drastically alter natural processes and are typically allowed in most wilderness tracts; such activities include grazing by domestic livestock, big game hunting, trapping, fishing, fire control, and recreational use. Hunting precludes studying the natural ecology and population biology of game animals. Hunters may also affect populations of nongame animals or even eliminate them from local areas as I had the misfortune to observe with hoary marmot (*Marmota caligata*) populations in a basin in the Goat Rocks Wilderness (Washington State). A major impact of fishing has been the introduction of fish into previously barren lakes, which has drastically altered the trophic structures. Recreational use differs widely in intensity, but its impact could be heavy and result in casual interference with plots or instruments.

Human activities also include the accidental introduction of exotic organisms, such as diseases and insects (for example, white pine blister rust, chestnut blight, gypsy moth, and balsam woolly aphid), which have drastically altered the natural ecosystem. Unfortunately, most of these impacts cannot be controlled or eliminated from wilderness ecosystems.

Scientific research can help us appreciate the substantive as well as the cosmetic changes that have occurred and continue to occur in wilderness tracts. Our general failure to appreciate how unnatural, however attractive, many of our wildernesses are frequently frustrates me. I think that wilderness management has focused on cosmetic rather than substantive issues. Wilderness users and managers are more concerned with the appearance of naturalness than with understanding and maintaining natural processes. This may be one reason why scientific use is tightly constrained; it is an activity that often has high visibility and lacks advocates, while other uses that subtly but seriously alter natural processes are allowed. Compromises necessary to pass the Wilderness Act in Congress guaranteed continued grazing and mining in National Forest wilderness, for example. Scientific investigation is not the major threat to natural processes in wilderness ecosystems; it does seem to be an easy target compared to greater threats, however.

INCREASING SCIENTIFIC USE OF WILDERNESS

What can be done to expand scientific use of wilderness? This assumes that there is general agreement on the desirability of greater efforts to extract the information resource of wilderness. Legislative clarification is one possibility, if there is really a question about the intent of Congress regarding scientific use of wilderness. There is always the chance of unexpected and undesirable outcomes from Congressional encounters, however, and the probability of not actually clearing away much fog. In fact, the issue may be one of agency attitudes and regulations and their interpretation rather than a legislative issue.

Zoning of wilderness is a possible way to deal with some conflicting uses. For example, segments of or even entire wilderness areas that have outstanding scientific values could be identified. Within such areas, recreational or other conflicting uses could be constrained, natural processes emphasized, and greater latitude in scientific methodology tolerated. Zoning is already practiced in many wildernesses, as shown by control of pack stock and allowance of semipermanent camps in some locations. The proposal for zoning is not a suggestion to be applied wholesale to the entire wilderness system but, rather, for limited areas identified after extended investigation.

Education is almost certainly an important step in improving scientific use of wilderness. Modified attitudes among managers, scientists, and users may be in order, and greater communication between these three groups is clearly necessary. I believe the importance of scientific study in wilderness to both the wilderness itself and society is not appreciated. The variety of research and equipment that might be used and potential impacts on natural processes and on appearances need to be clarified and discussed. The issue of cosmetic versus substantive impacts also needs to be aired.

Managers need to actively solicit and facilitate research, and not just that data relevant to their current problems. Some existing programs, such as the National Park Service's contribution to the National Acid Precipitation Program, provide excellent examples of how basic research can generate information of direct interest to wilderness managers. These programs also provide examples of cooperation between scientists and managers to carry out such research without significantly damaging wilderness values.

Scientists, for their part, have several obligations. They will have to accept logistical and methodological constraints on their research so that it fits within the wilderness ethic. Scientists need to develop improved techniques to conform with wilderness goals, such as methods involving minimum impact. Greater efforts to work with and inform managers are necessary. Colleagues and funding agencies, such as the National Science Foundation, need to be educated on the critical role of wilderness areas in ecological science.

Substantial involvement of scientists in wilderness planning could significantly expand the role of research and science in wilderness. Scientists could assist in identifying research needs and potential, including resources of special scientific interest, within specific wildernesses. In the process, they would become better informed of the opportunities and constraints and develop an effective dialog with managers and other user groups. Mutual education and promotion of the scientific use of wilderness would be an expected result of such involvement.

CONCLUSIONS

I have not emphasized research for the management of wilderness, although it is obviously critical. Such research is in short supply, but it at least has some constituency. I believe that we need to significantly expand appreciation of the importance of wilderness science, of knowledge from natural ecosystems to the World at large. There has been a lot of rhetoric, but the positive evidence of its value is now accumulating. Managers, scientists, and users need to work together to develop the mandates, procedures, and funds to use these most important outdoor laboratories.

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SCIENTIFIC ISSUES IN THE DEFINITION OF WILDERNESS

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ABSTRACT

This paper examines some of the important scientific issues underlying wilderness protection. Specific scientific criteria to define wilderness are identified, and the extent to which these criteria are incorporated within the process of preserving wilderness in the United States is discussed. Needed actions to highlight and protect scientific values in wilderness are discussed.

INTRODUCTION

A dominant theme in wilderness literature concerns the scientific values such areas hold. The purpose of this paper is to explore some of the issues that underlie the scientific values of wilderness, to identify some of the specific scientific criteria that contribute to the definition of wilderness, and to consider how adequately the U.S. Wilderness Act (Public Law 88-577) meets the concerns of scientists. Some concluding remarks discuss how these scientific concerns might be better met.

Wilderness is a term plagued by an enormous range of interpretation. Even in the United States, where it has acquired legal status, there remains considerable confusion; the term is often used to describe any area outside a developed setting. This confusion likely has its roots in the fact that wilderness in our culture is perceived as an antonym of civilization and, consequently, the concept is often used to describe any area not possessing the general qualities of civilization (Nash 1982).

For the purposes of this paper, wilderness describes those areas where management objectives feature protection of the natural processes that have shaped the physical-biological character of the setting. Mechanized access is prohibited or greatly restricted as are resource exploitation activities. Recreation is a legitimate use, yet subordinate to the goal of environmental preservation. Such areas provide a variety of values to society, including scientific values.

Calls for the protection of wilderness have been driven by many different concerns, including the desire to protect areas that provide primitive recreation opportunities; the need for protection of scenic resources; moral/ethical concerns, including protection of future options; concerns with the efficient use of resources; protection of the environment, particularly watershed and wildlife; and concern with the protection of important scientific values. It is these latter values that we are especially concerned with here; in the next section of this paper I want to discuss in some detail those specific characteristics of wilderness settings critical to science.

WILDERNESS AND SCIENCE

My focus here is on wilderness as a setting for research on the natural environment. Certainly wilderness is an important setting for human activity and many important research issues can address such use (such as how people organize and cope in natural settings, what benefits accrue to society from exposure to the natural environment). Many of these issues, however, could be investigated effectively in areas other than those where the setting is substantially unmodified by human activity. However, research on the roles of the structural components of unmodified ecosystems or the genetic diversity within such ecosystems is dependent on the availability of areas where human activity and impacts are minimal. Thus, research priorities in wilderness areas should focus on ecologically, not socially, oriented issues.

Although it is not my intention to argue the relative merits of basic versus applied research in this paper, it does need to be pointed out that much of the concern for a heightened role for research in wilderness focuses on the need for more basic investigation. This in no way denies the value of applied studies. If our pursuit of scientific understanding in wilderness, however, is limited to the acquisition of knowledge to mitigate or prevent problems, the frontiers of learning will be severely constrained. In fact, they would be effectively limited to those matters judged in need of immediate solution by managers. Development of a basic understanding of long-term processes and dynamics whose implications for management might become apparent only in the very long term would be forgone.

Many specific scientific values can be noted; most fall into one of the following three categories:

First, wilderness is valued as a setting that provides a baseline of the conditions in the natural environment that have evolved outside human influence. Leopold (1941) argued for the preservation of wilderness as a "land laboratory" where a base-datum of normality would be available for comparison with areas modified by human use and occupance. Few areas remain where the landscape is substantially unaltered and uninfluenced, making those areas all the more valuable from a scientific perspective (Cain 1960).

Second, wilderness provides a setting where the nature, role, and function of the various components and processes of the wilderness can be investigated, again away from sources of disturbance. Franklin's 1982 studies of the temperate coniferous forests of northwestern North America provided important insights into

the functioning of the various structural components of these forests. Such insights can lead to improved prescriptions for the management of areas outside wilderness. They also help reveal critical components that may be lost when areas are disturbed. For instance, Darling (1960) cited how the loss of sensitive pill millipede in eastern woodlands during timber harvest disrupts the conversion cycle in which detritus is converted to soil. Even when tree growth recurs, an essential element in the ecosystem has been lost, reducing the site's long-term productivity. Understanding these complex relationships and functions is contingent upon there being places where these processes are undisturbed; wilderness is one area where this is the case.

Finally, science is concerned with the long-term preservation of wilderness because there simply has not been adequate time or effort to discover all the values such areas possess. I am reminded of Leopold's assertion that such areas possess the answers to questions we have not yet learned to ask. The widespread loss of species, particularly in the tropical rain forests, carries with it an unknown impact on science. Myers (1979) estimated that, during much of the present century, about one known species per year has become extinct, but that because of the lack of knowledge about how many species even exist, the overall extinction rate among all species, whether known to science or not, could be at least 1,000 and conceivably as high as 40,000 per year. This latter rate would mean the loss of at least 1 million species by the end of the century. I can only speculate as to the benefits being lost to humankind, but it is likely that significant economic and social benefits are involved. Certainly one major concern is with the shrinking genetic base as human activity drives ecosystems to simpler, more spatially concentrated forms. The loss of gene pools in which ancestral diversity exists could mean that our ability to develop, for example, new variants of plant species would be greatly reduced (Cutler 1980; Myers 1979).

Wild lands, places where natural forces and their effects still predominate, thus possess great scientific value. But beyond this general observation, we need to pursue two important issues. First, what are the specific characteristics of wilderness settings that maximize their scientific value? And second, to what extent are these criteria explicitly addressed in the U.S. Wilderness Act? I turn to the first of these questions next.

SCIENTIFIC CONSIDERATIONS FOR SELECTION OF WILDERNESS

What specific wilderness considerations are important to science? It seems to me that four broad classes of scientific concerns can be defined. First, there are the specific characteristics of the area, including size, shape, boundary location, flora and faunal composition, representativeness, and successional stage. Second, there are concerns with permitted uses within the area, including recreation, exploitative activities, preexisting impacts, and fire exclusion. Third, the long-term security of the area, including its legal status with regard to permanent protection, as well as its susceptibility to impacts such as acid deposition from within as well as outside the area is a concern. Finally, there is a concern with the extent to which scientific values are recognized explicitly in the area's management policies, including the development of specific guidelines for scientific investigations.

Characteristics of the Area

An obvious and primary concern of scientists in the allocation of wilderness is the character of the area. Many specific concerns are involved. The appropriate size for nature reserves, for example, has long been a concern of scientists. It is important that reserves offer adequate protection of the area's environmental assemblage and ecological processes active in the area. Because most reserves are surrounded by areas under varying levels of development and modification, size offers a buffer to outside influences that might alter the natural character and processes within.

In addition to its role in protecting an area's ecological integrity, size is important in the maintenance of species diversity. Studies in island biogeography support the idea that, in general, larger reserves support a greater range of species (Diamond 1975; Simberloff and Abele 1976). Although the results of island studies have been criticized as to their applicability to continental situations (see Slatyer 1975), there remains general agreement that reserves need to possess a size adequate to protect the resources they contain.

What constitutes adequate size remains a complex issue. Research under way in Brazil under the auspices of the World Wildlife Fund and Brazil's National Institute for Amazon Research is designed to provide better understanding of the consequences of alternative reserve size on an area's capacity to preserve the principal characteristics of its ecosystem and to maintain biological integrity (Lewin 1984). Such studies could greatly aid both managers and scientists in determining what size wilderness reserves should be to achieve the purposes underlying their establishment.

Closely related to concerns with size are questions related to an area's shape and the location of its boundaries. Generally, compact shapes are preferred over distended forms, although for some species such as birds, connected lineal forms might be important in providing continuous habitat (Diamond 1975). Boundaries should incorporate all the critical components of the ecosystem; ideally, this should include topographically discrete units. If boundaries do not include all these critical components, the area's value for science is reduced; the effectiveness of the reserve is diminished by the lack of control over those areas outside the boundary (Polunin and Eidsvik 1979).

Perhaps one of the overriding concerns of scientists is the quality of the reserve's natural conditions. As Bourliere (1962) noted, parks and reserves (and we can include wilderness here) are the real laboratory of ecology. The naturalness of the communities, the diversity represented within them, and the representativeness of the system(s) are all major concerns.

Protection of a representative range of diverse ecosystems has been a long-term concern of many scientists. Although it is clear that wilderness classification cannot be expected to preserve the entire range desired, such reserves are an important component of any overall conservation program as it is in such areas that the undisturbed status of these systems can best be studied.

Many of the world's wilderness reserves owe their status not to unique biological characteristics, but rather to their scenic values or to the fact that they were available and had limited potential for other uses (Costin and Mosley 1969). Many wildernesses owe their protection not to any scientific criteria, but rather to the presence of strong public and political pressure (a perfectly legitimate rationale, I might add). Although subject to many criticisms, one important aspect of the U.S. Department of Agriculture, Forest Service's RARE II project was the effort to review and recommend, in a systematic fashion, areas for wilderness designation that possess biophysical characteristics currently not represented within the National Wilderness Preservation System (NWPS).

Biophysical representativeness in wilderness or similar reserves, however, is generally considered poor. At the international level, the Biosphere Reserve program is intended to conserve a representative sample of ecosystems and ecological zones (IUCN 1979). Worldwide, however, less than 250 such areas have been set aside (IUCN 1982). Of the 193 biogeographic provinces in the world (Udvardy 1975), 16 have no protection at all, and 33 are protected in fewer than five areas covering an area of less than 100 000 ha (Harrison and others 1984). In the United States, only about 100 of the 233 distinct ecosystems in the country (following the Bailey-Kuchler method) are represented in the NWPS (Davis 1980; Kirby in press). Adding wilderness reserves under the management of State governments expands this coverage somewhat, but still leaves significant gaps in ecological coverage (Stankey 1984).

Diversity is also an important quality of wilderness reserves, both within areas as well as across a system of reserves. The loss of wild landscapes, coupled with the tendency toward ecosystem simplification in modified environments, is leading to a steep decline in biological diversity. As Wilson (1984) noted, "In our own brief lifetime . . . deep mines of biological diversity will have been dug out and carelessly discarded in the course of environmental exploitation, without our even knowing fully what they contained." The loss of diversity also means a loss of genetic variety, with its associated consequences for scientific and medical research as well as other sectors of our lives (Myers 1979; Prescott-Allen and Prescott-Allen 1982).

Uses Permitted in the Area

The ideal of wilderness generally implies an absence of modern, technological human activity. In reality, a variety of human activities persist in such areas. This includes activities consistent with the area's classification as wilderness (such as low-density recreational activities) as well as preexisting uses whose continued pursuit is protected through law or other legal agreements (such as grazing and mining under the U.S. Wilderness Act or subsistence hunting and gathering in some African reserves).

Such uses and the impacts associated with them represent potential threats to the scientific integrity of wilderness. Two specific problems can arise. First, human use can alter the natural processes within the area through the introduction of exotics, the importation of nutrients, and the elimination of critical components of the ecosystem. Second, human activity, either accidentally or purposefully, can directly impact scientific investigations. We will return to this latter point in the next section.

Integrating scientific uses of wilderness with other permitted uses means compromise. It is important, however, to keep the impacts associated with these other uses in perspective. For example, although recreation is a major use of U.S. wilderness and possesses the capability of conflicting with various scientific pursuits, its highly concentrated nature often means that such conflicts are minimal. Cole (1981) found that in the Eagle Cap Wilderness in northeastern Oregon, only about 1.5 percent of the area had sustained impacts from recreation use, but long-term suppression of fire had resulted in subtle changes throughout the area. As a consequence, the primary impacts on the area, from a scientific perspective, stemmed not from current recreation use, but rather from policies constraining the use of fire. Similarly, the profound biotic impacts introduced along the Colorado River in Grand Canyon as a result of construction of Glen Canyon Dam far outweigh the significance of recreational impacts stemming from river runners, yet much of the concern with controlling impact is focused on the river's recreation use.

Although it would be desirable from the scientist's viewpoint if these other uses were not allowed, it is unlikely that sufficient political support could be garnered for the preservation of substantial tracts of land solely for scientific investigation. Although such strict preservation is possible for small tracts of land (research natural areas and other nature reserves), wilderness reserves offer much larger areas that provide more adequate ecosystem protection. The price paid for in size is the opening of the area to various other uses.

Long-term Security

A third element of concern to scientists (as well as to many other advocates) is the long-term security of the area's designation. The need for such assurances is recognized in IUCN's discussion of national parks; in such reserves, it is noted, "The highest competent authority of the country has taken steps to prevent or eliminate as soon as possible exploitation or occupation in the whole area and to enforce effectively the respect of ecological, geomorphological or aesthetic features which have led to its establishment" (IUCN 1982).

The issue of security involves two concerns. First, there is a concern with the permanence of the designation. If an area is established as wilderness, can we expect the protective designation to prevail in the future? Although any classification is subject to change, generally legal or statutory protection is preferable to

administrative protection. In the United States, the press for a wilderness law was driven in large part by concerns with the vagaries of the existing administrative system of wilderness protection.

A second concern regarding long-term security involves the extent to which the area is protected from influences that can adversely impact its natural integrity from within as well as outside. Although careful boundary location can avoid or mitigate external threats, we must remember that boundaries are largely the artifacts of administrative convenience and permeable to a host of influences. Although the analogy is perhaps overused, it remains an unfortunate fact that wilderness reserves are islands in a sea of development and modification. Hence, a major concern, along with the natural qualities within an area, is the nature of activity surrounding an area. The presumption that the integrity of an area can be fully protected within its established boundaries is ecological folly. Whether the surrounding lands are managed as a buffer or whether they are managed so as to integrate the objectives of the wilderness reserve with those of the adjacent lands, it is critical that the context within which wilderness exists be taken into account (Machlis and Tichnell 1985).

Even the above precautions are not adequate to protect a wilderness reserve from all threats. Today, growing international concern with acid deposition highlights the interdependent nature of our environment. Such a threat jeopardizes many of the scientific values wilderness contains; inadequate baseline data regarding pH levels in pristine water courses also hampers the ability to fully assess the nature and rate of acid deposition on our environment.

Security is a major concern of scientists because much of the research that needs to be conducted is long range. The value of such projects, and their benefit to society, are dependent on the investigators being able to follow changes in the environment over extended periods with minimal outside influence. Disturbances could result in the loss of potential benefits that such long-term research would otherwise produce.

Guidelines for Scientific Research

A final concern deals with the existence of specific guidelines and criteria that recognize and promote research in wilderness. As noted earlier, protection of scientific values in wilderness areas has been a common concern. Beyond this general concern, however, there remain specific questions with regard to how these scientific values might be best protected.

Several issues seem important here. These include the development of guidelines for appropriate use by scientists. Because much of the research would be long term, careful field marking becomes critical so that sites can be accurately relocated (Franklin 1984). Certain scientific work will require the taking of samples such as wedges or cores for fire history dating. Because wildernesses are generally areas where evidence of human use is minimal, sampling needs to be done as sensitively and unobtrusively as possible. More specific attention needs to be given to the question of the nature of research activity to be permitted. I suggest that, in most cases, research be limited to observational studies as opposed to experimental work. Experimentation seems to involve activities that are contrary to the general concept of allowing natural processes full sway. Some research activities fall into a gray zone; for example, the reintroduction of fire into fire-dependent ecosystems where long-term suppression has greatly altered the character of the ecosystem, resulting in historically unnatural fuel accumulations.

One excellent example of an effort to develop the kinds of guidelines discussed here can be found in a publication of the Australian Academy of Science, entitled *Scientific Research in National Parks and Nature Reserves* (Australian Academy of Science 1980). This publication provides a discussion of the role of science in such areas, the distinctions and value of applied as well as basic research, and the responsibilities of both managers and scientists with regard to research projects. It also offers some useful suggestions for minimizing conflicts between scientists working on research projects in reserves and area managers and users. These include: being intimately acquainted with the laws and policies governing the area, maintaining careful control of all work, particularly that which might result in undesirable impacts on natural processes, and providing periodic feedback on results to area managers.

RESEARCH UNDER THE U.S. WILDERNESS ACT

It is useful, in this closing section, to review the extent to which the U.S. Wilderness Act satisfies the various criteria discussed above. Of course, in addition to the law, individual organizational policies have evolved and these policies further define the role research has taken. Jerry Franklin has commented on these in his paper (this proceedings).

The U.S. Wilderness Act clearly calls for the protection of an area's natural qualities. Such areas, the Act declares, involve ". . . undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable." The Act also addresses the size issue, stating that a wilderness contain at least 5,000 acres of land or be ". . . of sufficient size as to make practicable its preservation and use in an unimpaired fashion." It is clear from the legislative debate that the elaborative clause here was intended to allow the addition of areas smaller than 5,000 acres (such as islands), not to require that areas encompass complete ecological units. Finally, the Act contains language indicating that such areas may also contain ". . . other features of scientific . . . value."

The U.S. Wilderness Act contains no specific provisions regarding the selection of either representative or unique biophysical areas. Nor does it contain language regarding appropriate boundary locations. And although it recognizes that wildernesses may contain scientific

values, it provides no special language to encourage or facilitate scientific investigations.

Nonetheless, it seems clear that a major role for science was envisioned by the Wilderness Act. It notes that wilderness "shall be protected and managed so as to preserve its natural conditions . . ." and that each agency administering wilderness "shall be responsible for preserving the wilderness character of the area." The capacity to meet these requirements rests substantially on the possession of an information base that allows managers to enact appropriate policies. It is from scientific investigation that much, though not all, of this knowledge derives (Leopold 1969).

Organizational response to the need for acquiring information of a scientific nature has varied. In a paper prepared for this proceedings, Butler and Roberts (1985) reported that research in the Forest Service and National Park Service varied in both extent and nature. In surveying research activity in 53 national forest wildernesses and 22 national park wildernesses, they report nearly 3.5 times as many research projects in the national park areas as in the national forest areas. Moreover, while nearly two-thirds of the research on the national forests was focused on recreation, only 2 percent in the national parks was. One-third of national park research focused on zoology, and nearly 20 percent each on botany and the earth sciences. The authors attribute the differences to a variety of factors, but in particular note the strong Forest Service concern with minimizing even research impacts and encouraging research outside wilderness.

Forest Service wilderness policy regarding research is strongly oriented toward applied studies. For example, policy noted in Forest Service Manual 2324.41 is "to conduct research to meet the needs of the act." A critical issue here is who defines "needs" and by what criteria. It goes on to state that policy with regard to research is to identify needed research in wilderness management plans, ensure that wilderness is essential to the request (that similar opportunities outside wilderness do not exist), and to mitigate conflicts to the extent feasible. Motorized or mechanized equipment is prohibited unless the research cannot be done another way. The recent request of the Environmental Protection Agency for permission to use helicopters during sampling of acid deposition in wilderness lakes in the West is an example of a negotiated arrangement where mechanized access is allowed. (The agreement permits mechanized access only when completion of certain chemical analyses of samples could not be achieved within critical time frames using foot or horse travel.)

The role of science and scientific investigations in wilderness is a controversial one. Science can be seen as one of the many interests clamoring for opportunities to further its aims. At one extreme we find the view that "research is a vested interest . . . although the . . . research worker may be altruistic and high-minded, he is funded and not invisible. Research workers . . . are rarely conscious of their own social, economic and environmental impact" (cited in Australian Academy of Science 1980). On the other hand, Franklin (1984) observed: "[we] do not propose scientific license in the use of reserves . . . or use of conspicuous markings in recreationally sensitive areas."

What seems to be needed is a clearer understanding of the critical scientific role that wilderness plays. Scientists must take greater initiative to underscore how wilderness reserves benefit society as a source of knowledge. At stake here may be the very success of maintaining and expanding our wilderness system. Over the past several years, for example, recreational use of wilderness has begun to stabilize, and when one examines the demographic structure of our society, it is likely this trend will continue. With it we can expect pressures to retard the growth of the wilderness system and possibly even to declassify some areas on the grounds that demand does not warrant so much area being classified as wilderness (the National Wilderness Preservation System presently contains about 89.5 million acres). Implicit in such a perspective is the view that the supply of wilderness should be tied directly to the recreational demands placed upon it. If this view prevails, however, it would mean the irreversible loss of many key wilderness settings. It seems important in response to such a view that we better define the full range of benefits that accrue to society from a program of wilderness preservation. Key among these are the scientific values such areas possess. In fact, a strong argument can be made that improved scientific utilization of wilderness represents a major way of conveying the benefits of wilderness to a broader sector of society than just recreation users.

Also, it seems clear that if science does not take a more active, even aggressive, role in asserting its interest in wilderness, it might well find its role relegated even further down the list of priorities. As Franklin (1984) has noted, "The scientific community must begin to put up or shut up; if we do not use our scientific reserves we will almost certainly lose them." The situation does not appear to be improving. Over 20 years ago, Cain (1960) remarked, "Many of us are caught, by stating that wilderness must be protected because of its value for scientific research, in an apparently untenable position . . . unable to point to any significant research already performed in the wilderness tract under question."

SOME NEEDED STEPS

Although America's large wildernesses hold great appeal for scientific inquiry, we must also recognize that such areas are not just large nature reserves or natural areas. They are wildernesses, with a particular meaning and purpose ascribed to them through the legal process. Scientists, along with other interest groups, must abide by these guidelines. Yet there remains the persuasive argument that science and scientific inquiry offer an important way of justifying the significant investment that society has made in the wilderness system. The principal gain is in acquiring a better understanding of how the natural world operates. Whether this translates into specific guidelines on how to manage these areas or simply represents an addition to the store of human knowledge, perhaps but not necessarily of benefit at some future time, does not seem to be a critical concern.

Several steps seem called for to capitalize on the scientific opportunities offered in wilderness. First, scientists must do a better job of conveying to citizens, politicians, and policy makers the significant scientific values contained in wilderness and the critical need to explore these values in depth. Care needs to be taken to develop realistic expectations; not all scientific discoveries will lead to direct benefits to society. The nature of scientific inquiry, however, is such that there must be latitude to pursue avenues of investigation free of the necessity of always being able to demonstrate immediate utility. Yet there seems to be sufficient cause to presume that enough short-run benefits will, in fact, accrue to warrant the commitment of societal resources to underwrite the needed research effort. Scientists face a major selling job in achieving this goal and, although not a new point, it needs to be emphasized that science needs to bring the mystery and excitement that accompanies it to lay audiences. Doing so will likely have major returns; I am convinced there is a latent public interest in the secrets of the natural environment that requires a creative, sensitive approach. The fine, popular television series on BBC produced by David Attenborough confirms how well received science can be.

Second, for science to better highlight the opportunities in wilderness, a more encouraging environment for research activity must be fostered. Although science must ensure that its activities do not jeopardize the processes and qualities that give wilderness its unique value, the potential contributions to society that will result from improved scientific understanding of these areas and the processes that shape them seem to warrant a broader and more flexible role than presently exists.

To address many of the concerns that likely underlie the fairly restrictive approach to research activities in wilderness, it would seem useful to establish a set of guidelines and principles to clarify what constitutes appropriate wilderness research activity. As suggested earlier, such a document should address issues such as sampling, the location of research activity, relationships between managers and researchers, and experimentation. The aforementioned publication *Scientific Research in National Parks and Nature Reserves* by the Australian Academy of Science is an excellent example of such a document. Basically, such a publication would establish a code of conduct for the scientific use of wilderness by codifying an agreed-upon set of norms for the definition, conduct, and dissemination of knowledge. It would provide the public, area managers, and scientists with clearly defined expectations about scientific activity in wilderness and would serve to highlight the importance of such work.

Finally, because it is difficult to accurately gauge either the amount or scope of current scientific work in wilderness, it is correspondingly difficult to build adequately a case for its existing, let alone potential, value. Some well-defined central repository of wilderness-based research is needed, a central clearinghouse that documents the location, nature, and scope of research activity. Such a location would offer those concerned with communicating the scientific values of wilderness an easily accessed source of information, either with site-specific data or with results from which they might be able to extrapolate to their situation (or get in contact with scientists who could assist them in doing so). And it would provide other researchers with an improved ability to identify research needs and opportunities for replicative research. Also, it would serve to better integrate studies from differing disciplinary perspectives. A good example would be the Sierra Club publication *Research Projects in the Sierra Nevada, 1970-1973* (Stanley 1974) that identified all the research undertaken in that area irrespective of disciplinary focus or organizational sponsorship.

In summary, an increased effort to document the critical scientific values contained in wilderness and to build a persuasive argument for ready, responsible, scientific access to these values is called for. Although there might remain some areas of conflict between the interests of science and those of the general public in wilderness, there is a great opportunity for the scientific community to capitalize on the significant public interest in, and support for, wilderness. Only in this way can we more nearly achieve the objective of securing "for the American people of present and future generations the benefits of an enduring resource of wilderness."

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WILDERNESS POLICY—AN INTERNATIONAL PERSPECTIVE

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ABSTRACT

Legislated wilderness is a concept well developed and understood in only a few highly developed and economcally healthy countries. It is a concept hard to translate and more difficult to internationalize across cultures. A more appropriate way to popularize wilderness may be to widen its definition to include a zone management strategy rather than always separate legally designated units. Several established IUCN management zones exist that such a strategy could be used in.

INTRODUCTION

This paper explores wilderness from a global point of view, using the United States (U.S.) only as a point of reference. The key issue here is, where has the wilderness concept, in a legal sense, succeeded and where has it failed? There are many other aspects to wilderness. I have not, for example, focused on its emotional values or on its value as a rallying point for the protection of natural areas. With this proviso, I would like to make some observations on the current situation and on future opportunities.

Wilderness defined in legislation is a concept almost unique to the United States. It has gained some recognition in Australia, Canada, New Zealand, and South Africa. Of some 160 countries in the world, 155 have not acted on the wilderness message. Only in the U.S., Canada (three Provinces), and South Africa have wilderness areas been established under legislation. New Zealand is about to designate its first area. In other countries, wilderness is a zoning mechanism.

DEVELOPMENT OF THE WILDERNESS CONCEPT

Countries with legislated wilderness all share European roots. Early European use of the term "wilderness" referred to barren or uncultivated lands usually outside settled areas. However, even in 1681 Hampstead Heath in London was described as a "barren wilderness" in urgent need of cultivation (Thomas 1983, p. 27).

In 16th century England, current concepts of conservation were nonexistent. Society was utilitarian—"the artificial preservation of uncultivated hilltops would have seemed as absurd as the creation of sanctuaries for wild birds or animals which could not be eaten or hunted" (Thomas 1983, p. 14). Now in some ways, perhaps not much has changed. Much of human civilization remains virtually synonymous with the conquest of nature.

As 200 years drifted past, we found Americans, Canadians, Australians, and a few others all set to conquer the wilderness. By then wilderness had become the land at the edge of settlement—the frontier. Concepts of remoteness and ruggedness combined with a struggle for survival left little doubt that the enemy was wilderness.

About the middle of the 19th century, new perceptions of the frontier began to appear. Catlin and Muir, among the founding fathers of conservation, described it as a thing of beauty to be preserved. Soon, Yosemite (1864) and Yellowstone (1872) appeared on the scene. A new social concept was born in Yellowstone, a public park and pleasuring ground.

Across the Pacific in Australia, Hacking National Park was established. Now called Royal National Park, its centennial was celebrated in 1979. Today's concept of national parks was established. However, Sir Henry Parkes had this to say: "It is a wilderness and . . . years must elapse before it can be of any use" (Mosley 1978a, p. 27). It is clear that wilderness was not to be preserved for its intrinsic values. The utilitarian values assigned by Europeans to wilderness continued to be dominant.

Banff National Park was established as a "public pleasuring ground" in 1885. In New Zealand, Tongariro National Park followed in 1887. Turning to South Africa, we find more than a dozen large nature reserves established in the 1890's (IUCN 1984). All of these could, to a greater or lesser degree, be described as wilderness.

With one exception (Mexico), it appears that those countries that began their protected area systems prior to the turn of the century (IUCN 1984) are also the key figures in the wilderness movement. Another common attribute of these countries is that they are all countries with a sound economic base. It would appear that a "full belly" is a prerequisite to wilderness establishment.

Looking beyond the magnificent wilderness efforts of Robert Marshall, it strikes me that the next big push came in the 1950's.

In the early 1950's there was a real concern in the conservation community that what had been gained through the national parks movement was in real danger of being blacktopped. Burgeoning park visitation and the "Mission 66" program created a concern that no roadless areas would be left. In the U.S., one reaction to these concerns was the 1964 Wilderness Act that applied to national forests, national parks, and other Federal lands.

This need for additional protection had not hit the rest of the world, which was just beginning to get its first tier of protection established and was not subject to intensive park use. Traditional mechanisms of nature reserves, game sanctuaries, and national parks were gaining acceptance.

WILDERNESS AS A CULTURAL CONCEPT

In the developing world the concept of "wilderness" is an idea whose time has not arrived. Not only has its time not come, but there continues to be considerable confusion in the developing world about the meaning and values of wilderness. This subjective nature of wilderness was described by Nash (1967, p. 1):

> "Wilderness" has a deceptive correctness at first glance. . . . There is no specific material object that is wilderness. The term designates a quality . . . that produces a certain mood or feeling in a given individual and, as a consequence, may be assigned by that person to a specific place. Because of this subjectivity, a universally acceptable definition of wilderness is elusive. . . . Wilderness, in short, is so heavily freighted with meaning of a personal, symbolic, and changing kind as to resist easy definition.

I agree with Nash without difficulty. I also, however, agree with an Australian colleague who said, "We can't get anywhere unless we have sorted out our own terminology" (Smith 1978). In this respect, while there may be accepted definitions applied in the U.S., there does not appear to be an agreed-upon international terminology.

Wilderness is a value-loaded word. It is a word full of emotion on one hand and yet used with legal precision on the other. As an emotive word and a cultural concept, it is a powerful tool for conservation. However, we also use it in a legal sense—sometimes to define a zone in a park, a zone in a national forest, or a discrete new type of protected area. In this there is a danger of debasement. The original idea of large, primitive, remote areas remains important to the concept. When wilderness in the legal sense becomes 5,000, 3,000, or even 5 or 6 acres, it appears to me to have lost usefulness.

Wilderness has great value in the global cultural context. One need only read some of the early writing—whether Thoreau, Muir, Leopold, or Marshall or alternatively, the proceedings of the Third World Wilderness Congress—to gain a sense of its powerful impact on individuals. Yet, when we begin to use the term in a strict legal sense, it loses its impact. It lacks clarity; it lacks definition, and as a result has not been taken up as a conservation tool by many countries. It is this latter point that I am focusing on—if it is possible to focus on this wonderful, elusive thing called wilderness.

Having outlined some background, where do we in "the international conservation establishment," as defined by McCloskey (1984), go from here? He states that the International Union for Conservation of Nature and Natural Resources (IUCN) has a bias against wilderness, and that "the word 'wilderness' is almost regarded as a dirty word - a word that is better not mentioned" (McCloskey 1984, p. 1).

I don't admit to that bias, but I do agree with Mr. McCloskey when he says, "People kind of look askance at you if you want to use the word wilderness, as if Americans have some peculiar penchant for that term" (McCloskey 1984). Frankly, I think this is true, but I see nothing wrong with it. Wilderness, as defined in the 1964 Wilderness Act, has served the U.S. people well, increasing protection in the national parks and creating new wilderness areas on national forests and BLM-administered lands. This does not necessarily mean it is a good or timely concept for the rest of the world. Nor does it mean that IUCN is opposed to it. On the contrary it is a good concept, in the right place, at the right time.

SOME GLOBAL PERSPECTIVES

From a global perspective there is a barrier in terminology. More fundamentally the language itself sometimes creates a barrier. My Spanish-speaking colleagues tell me there is no such word as "wilderness" in the Spanish language. On top of that, any translation is awkward. Similar problems arise in the French language. Thus, we are limited by vocabulary from easy communication about wilderness with much of the world.

Three World Wilderness Congresses (South Africa, Australia, and Scotland) have tried with only limited success to spread the wilderness message. The message remains diffuse. No one has defined acceptable criteria for concerns such as: how big should wilderness be; how remote should wilderness be; how pristine should wilderness be? I believe these are critical values or qualities; without guidelines, individuals are left to wrestle with biological values and then with anthropocentric perceptions, and finally with combinations of both. A quick global tour will expose the current situation and various conceptions relating to size, remoteness, and quality.

The Question of Size

North America.—Early Forest Service guidelines for primitive areas as wilderness were 230,000 acres; later this became 100,000 acres (ORRRC 1962). In 1964, the U.S. Wilderness Act brought this down to 5,000 acres; last year, Michigan legislation dropped it to 3,000 acres. In the early 1960's, Ontario wilderness areas were restricted to a maximum of 640 acres. Today a few wilderness islands are only 5 acres.

My personal bias suggests that we are not talking about wilderness in areas of 5,000 or 3,000 acres. These should be exceptions and not standards. We should use other terminology; perhaps roadless areas, perhaps nature sanctuaries, but surely not wilderness.

Australia.—A New South Wales study recommended a minimum area of 25 000 ha (62,000 acres), with a core area at least 10 km in width and a surrounding buffer zone of 25 000 ha (Mosley 1978b). This definition brings us back much closer to the earlier Forest Service definition of 100,000 acres.

New Zealand.—In New Zealand, wilderness areas must be large enough to take at least 2 days' foot travel to traverse (Govt. of N.Z. 1985). Depending on the terrain, one would anticipate that wilderness areas in New Zealand would exceed 50,000 acres.

The United Kingdom (A Unique Perspective).—Vice Admiral Sir Robert E. Brockman suggested a wilderness boundary based on the distance an average man could

see if standing on a smooth sphere. His average man, 1.6 m tall, could see 5.6 km to the horizon. This would result in a circle approximately 30,000 acres in area (Brockman 1979).

The Question of Quality: How Pristine Should Wilderness Be?

A global perspective.—With nuclear submarines prowling under the Arctic icepack and tourist-laden jets crashing into Antarctic mountains, we may have lost our last wilderness. As Brower wrote in 1977, "There is no pure wilderness left. Radioactive fallout and the oozing of wastes have left no corner of the earth clean." This degree of purity could be described as one end of the continuum.

An Antarctic Perspective.—"There is unfortunately no true wilderness left. Global pollution has ensured that even Antarctica shows traces of industrial contamination - radioactive fallout and heavy metals have all been detected in Antarctica ecosystems" (Tierney and Johnstone 1978). Again, we are at one end of the continuum.

Two Views From the United Kingdom.—"There is no part of Britain that has not been grossly influenced by man" (Brockman 1979). However, the Admiral goes on to suggest that England's Dartmoor moorland offers a wilderness experience to urban man. No doubt it does, but I would question the authenticity of a wilderness that contains the following: prehistoric dwellings, stone monuments, sheep (necessary to clip the moors), a conifer forest plantation, a 231-meter TV tower, two small reservoirs and ancillary dams, a military presence involving the live firing of small arms, artillery, and mortars—separated in time and space from visitors. Add 150,000 children among 450,000 annual visitors to the wilderness. Take these away from the 8 million visitors to Dartmoor National Park and you have one man's wilderness and another man's zoo. The Admiral recognizes this and adds, "In a democracy how many coloured anoraks can you afford to see, before the wilderness ceases to be your wilderness?" (Brockman 1979, p. 207). This is, of course, the other end of the continuum.

Jamaican Perspective.—"In Jamaica, parks, recreation and wilderness are something of a luxury" (Young 1979).

South American Perspective.—We do not use the term "wilderness;" it has no meaning in Spanish (Dourojeanni 1984).

The Question of Remoteness

Australia.—As a beginning, ". . . one cannot have wilderness at the roadside or road's end because it is not remote from people, transport facilities, and other man-made aids. . . . The minimum degree of remoteness necessary for this wilderness seems to be that at least half a long day's travel is needed before one has even reached wilderness - say 10 km" (Smith 1978, p. 21).

Remoteness brings into play the question of buffer zones and options that would include or exclude them from wilderness. The U.S. position to begin at the roadside clearly differs from that of Australia and, as well, New Zealand.

SOME CONCLUSIONS

Having looked at a number of factors, we must decide whether our objective is to protect all roadless areas, no matter what size, as wilderness. Alternatively, is the objective to increase protection within existing protected areas? Or is the concept of setting aside discrete areas, 30 000 ha or 50,000 acres in size, remote and pristine, distant from the sights and sounds of man, still valid? If so, how can it be achieved?

It strikes me that if we focus on legislated wilderness as the only solution, we will continue to distort what appeared to be the clear objectives of large size, remoteness, and pristine qualities. We will end up with a word that means nothing, or means whatever you want it to mean. Simply put, the three essential requirements of wilderness are size, remoteness, and natural qualities. We need a rededication to these functions.

THE FUTURE POTENTIAL

If there were no potential wilderness areas, it would be folly to go on from here. To check what potential exists, I reviewed the prepublication draft of the 1984 United Nations List of National Parks and Protected Areas (IUCN 1984). To keep the task manageable, I made a list of all protected areas over 500 000 ha. These are outlined in table 1.

Table 1.—Protected areas over 500 000 ha in size (K = 1 000 ha)

Size	No. of areas
+ 500 000 ha	69
1 000 K but < 2 000 K	41
+ 2 000 K but < 3 000 K	19
+ 3 000 K but < 4 000 K	3
+ 4 000 K but < 5 000 K	4
+ 5 000 K but < 6 000 K	3
+ 6 000 K but < 7 000 K	0
+ 7 000 K but < 8 000 K	1
+ 70 000 000 ha	1
	141

The 70 million-ha area is Greenland National Park. Other high potential areas include: Salonga in Zaire, Kluane-Wrangell/St. Elias (Canada-U.S.A.), Kakadu in Australia, Manu in Peru, and areas on Irian Jaya, Indonesia.

In reviewing future action, it is important to remember that many of the 141 areas are still wilderness-like and are included in the above figures as are some legislated areas. However, for some of the reasons enunciated earlier most countries have not seen a need to create legal wildernesses.

Even in a "quick and dirty" overview such as the above, it is evident that within the world's existing network of protected areas containing some 400 million ha (McNeely and Miller 1984), there is ample potential to increase protection by applying wilderness concepts.

As a secondary consideration, I reviewed the 1984 United Nations List of National Parks and Protected Areas for countries with more than 10 million ha of protected area, perhaps with the naive thought that these might be targets for further study. In addition, I noted 10 countries with more than 5 million ha of protected area:

Country	Size (ha)
United States	[1]80 000 000
Denmark (Greenland)	70 000 000
Australia	34 000 000
Canada	21 000 000
U.S.S.R.	14 000 000
Indonesia	12 000 000
Botswana	11 000 000
Brazil	11 000 000
Chile	11 000 000
Tanzania	10 000 000

[1]Includes designated wilderness.

A FUTURE APPROACH

I mentioned earlier that very few countries had taken the approach of legally designating wilderness. On the other hand, wilderness as a management zone within park management plans is gaining acceptance.

Zoning is a reflection of the 1962 Outdoor Recreation Resources Review Commission (ORRRC) studies, the Second World National Parks Congress, propagation of the concept through the activities of the International Seminar on National Parks and Equivalent Reserves, the efforts of IUCN's Commission on National Parks, and many other proponents of management plans for protected areas. Zoning as a management tool was one of the most significant products of the 1962 ORRRC studies—the concept should be reinforced in ORRRC II.

IUCN has established 10 categories of protected areas (IUCN 1978). These are listed in table 2. Each type of protected area requires a management plan and each plan incorporates several zones, one of which could be wilderness.

Wilderness as a zone could readily fit into protected area categories 2, 4, 8, 9, and 10. Such designation could be made in the management plan with a stipulation that change requires public consultation or revisions in legislation.

CONCLUSIONS

It is clear that the legal designation of wilderness has taken hold in developed countries with a long tradition of protected area management. As a zoning concept wilderness exists in many countries, including Australia, Canada, Dominica, Ethiopia, Indonesia, Kenya, Thailand, and the U.S.A.

It is also clear that in the United States the original concept of wilderness as large, pristine, remote areas was changed by the 1964 Wilderness Act. The minimum standard of 5,000 acres has slowed the blacktopping of America's national parks. The Act has resulted in very significant additions to the wilderness network of the Forest Service and other Federal agencies, but it has also obscured the original meaning of wilderness.

We should not fail to recognize that we need to reach political decision makers to create new protected areas.

Table 2.—IUCN categories of protected areas

Category	Brief explanation
1. Strict nature reserve	Basically for scientific purposes, no manipulation, highest degree of protection
2. National/State/Provincial park	Designation depends on legal authority, would contain several zones
3. Natural landmarks/monument	Classic examples of features, generally not total ecosystems
4. Managed nature reserve	Ecosystems manipulated to favor certain plant or animal species
5. Protected landscape	A mix of cultural and natural features—U.K. national parks, French regional parks
6. Resource reserve	A holding category pending more data to make allocation decisions
7. Anthropological reserve/ traditional land	A reserve to permit acculturation or not, based on tribal desires
8. Multiple-use area	Management practices similar to those of the Forest Service in the United States
9. Biosphere reserve	International designation, representative area
10. World heritage sites	International designation, unique area

To get action we need a broad constituency. In many countries this support for wilderness does not yet exist.

If wilderness is to be used as a management tool for increasing the degree of protection in existing protected areas, I believe this can be achieved through zoning. Finally, if extensive new wilderness areas are to be established in the less-developed countries, it is my view that the same objectives can be more readily achieved by linking the wilderness concept, through zoning, to one of the existing IUCN categories of protected areas.

An expanded preamble to the protected areas categories paper could greatly elaborate on the value of wilderness that we all recognize and hold dear.

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RESEARCH NEEDS FOR WILDERNESS MANAGEMENT— AN UPDATE FROM THE NATIONAL WILDERNESS MANAGEMENT WORKSHOP

Edwin E. Krumpe and William J. McLaughlin

ABSTRACT

In 1983, participants at the National Wilderness Management Workshop focused attention on "taking care of what we've got" by identifying the critical issues that face wilderness management. Five broad categories of issues were: educating the public, education and training of managers, capacity and concentrated use, interagency coordination and consistency, and wilderness management practices. Of the 23 priority actions recommended to address these issues, 11 specifically require both basic and applied research. Specific suggestions for the role of research are offered for each of the 11 actions.

INTRODUCTION

It is particularly relevant that we gather to discuss wilderness research in light of recent events affecting wilderness management. Additions to the National Wilderness Preservation System have increased the total area permanently protected from 15 million acres in 1964 to 88.6 million acres in 1985. Numerous additions in the East have brought wilderness to the very back door of over two-thirds of our Nation's population. Reports on threats to the National Parks; the specter of acid rain; the threatened demise of our grizzly bear; and eminent development of mineral, fossil, and geothermal resources next door to our parks and wilderness areas have helped sensitize the public to the delicate nature of our wildlands.

In the 21 years since passage of the Wilderness Act, we have finally put to rest the myth that wilderness requires no management (for example, Lucas 1973). Rather, both the managing agencies and the public have come to realize that we may indeed risk "loving our wilderness areas to death" through overuse, trampling, crowding, and impingement on personal freedom. The basis of this realization has come from the recognition that the hallmark of wilderness is its NATURALNESS—a place where the earth and its community of life are untrammeled by man, where natural ecosystems and natural processes are allowed to prevail as they have from time immemorial. This is not a new idea. It was recognized by the early founders of the National Parks, by foresters such as Bob Marshall and Aldo Leopold, by the authors of the Wilderness Act, and by the millions of conservationists and citizens who have worked to establish and perpetuate the wilderness system we have today.

In fact, it was this growing recognition that wilderness needs protection and that all is not right with our wilderness that gave impetus to an earlier national conference such as this that focused on "taking care of what we've got." I refer to the National Wilderness Management Workshop hosted by the University of Idaho Wilderness Research Center in October of 1983 (Frome 1985).

MANAGEMENT CONFERENCE GOALS

The theme of that conference was not research, but rather the management of our existing wilderness preserves. Our goal was to focus attention on identifying the critical issues that face wilderness management. We had an outstanding array of speakers and participants, many of whom are here today. But the heart of the conference was a series of small, structured working groups in which all attendees worked together to identify the issues and assign priorities to them (Krumpe 1985). This was not an easy process, and the 38 working groups identified approximately 1,000 issues. Besides the breadth and scope of the issues, perhaps what was most revealing was how much remains to be learned about managing natural ecosystems in diverse settings. Anyone who had come expecting simple answers was most certainly disappointed. For in reality, more questions were raised than were answered.

In fact, this initial identification of issues led Forest Service Chief Max Peterson to coordinate with the directors of the National Park Service, the Bureau of Land Management, and the Fish and Wildlife Service in calling for development of an action program to address these issues. As many of you may know, a national steering committee was formed with representatives of outfitters and commercial recreation interests; public and private fish and wildlife organizations; citizen organizations active in recreation, conservation, and preservation; research and educational interests; along with the Federal agencies. The committee's task was to solicit broad public involvement in pulling together the

ideas generated by the workshop participants into an action program. Wilderness Management—a Five-Year Action Program (1985) is the published report that identifies and defines issues facing wilderness management and recommends actions to be taken by managers, by conservation organizations, by interest groups, and by private citizens. The issues are broad and the recommended actions cover a wide range of activities, many of which will take years to accomplish. Once again, we may have raised more questions than we answered.

Thus, when Dr. Glenn Haas, who in the early stages of coordinating this conference, expressed some concern to me that another conference in 2 years' time from our workshop would be repetitious, I heartily assured him that it would not. If anything, the National Wilderness Management Workshop pointed out a glaring need for more information and research to address the complex issues facing the management of wilderness ecosystems. Likewise, the Symposium and Workshop on Wilderness Fire, held in Missoula 1 month after our workshop, revealed that much was yet to be learned through scientific research, as did the Symposium on Wilderness and Natural Areas in the East conducted in May in Nacogdoches, TX.

Let me hasten to add, I see this call for research not as a self-serving plea by scientists to sustain their livelihood. Rather, I see a growing awareness and realization that much more knowledge and information is desperately needed if we are to ensure that wilderness resources and values are to be maintained and perpetuated for future generations. The Five-Year Action Program was aimed at improving wilderness management through 23 comprehensive recommendations that cover all aspects of wilderness management. Within these there is a clarion call for scientific research and study. Let me review for you 11 of the 23 recommended actions that call for further research.

EDUCATING THE PUBLIC

Of the five broad categories of issues, educating the public was the first listed. Successful plans and programs for resource management are wholly dependent on public understanding and acceptance. So it is with wilderness: as popularity rises and visitors come from nearby and afar, public understanding is essential to achieve respect for the resource, restraint, and willingness to adhere to appropriate uses. Such public understanding in many cases provides the desirable alternative to imposition of regulations and restrictions.

The first recommended action was to examine existing wilderness education techniques and evaluate their effectiveness, being sure that wilderness education material defines the wilderness resource and its values. At the workshop and in the followup public comment, numerous people expressed a belief in the importance of education as a management technique, while at the same time raising the question of how effective these efforts really are. This is a fertile field for research with potential to have important impact on wilderness management. Are wilderness information and education materials reaching the right people? Do people listen to or read them? Do they understand or remember the messages? To what extent does the material actually contribute to improved behavior in the wilderness? What things work well and what do not work very well, and why? These are some of the many questions concerning educating the public that require research to find the answers.

EDUCATION AND TRAINING OF MANAGERS

Workshop participants and the public at large identified a critical need to continually provide managers with education opportunities, updated information, and inservice training to enhance their ability to sensitively manage wilderness. Although some good work is being done in this area, managers often have limited access to such training; the workshops and training sessions are sometimes sporadic and may lack continuity or depth of coverage. The recommended action to institute and revitalize comprehensive inservice training utilizing both agency and nonagency expertise has direct relevance for researchers. As the agenda for the National Wilderness Research Conference amply illustrates, our knowledge base is growing exponentially. It becomes an opportunity and an obligation for researchers to translate their findings into understandable facts and concepts for the education of wilderness managers. The agencies sponsoring your research need to plan and budget for this followup as a part of the research projects. Whether you are involved in basic research on some natural species or phenomenon, or are scientifically collecting management information, the call for technology transfer is critical for today's wilderness manager.

Another opportunity for research will develop as the education and training of managers improve. Managers are continually conducting field miniexperiments when they implement management practices. All too seldom do researchers apply the scientific method to help design and evaluate these management practices. As we translate our research from the jargon of journals and ivory towers into useful concepts and applications, managers will more readily seek our advice and assistance in applying and utilizing research to solve management problems.

CAPACITY AND CONCENTRATED USE

Clearly, a third major category of issues facing wilderness management that was identified at the workshop is the problem of capacity and concentrated use. Within many wilderness areas are signs of trampling; erosion; damaged trees, plants, and natural features; introduced species; user-built structures; crowded campsites; human waste and litter; and user conflicts, to name but a few problems. Indeed we are in danger of "loving wilderness to death." Yet where use is restricted, other problems are likely to arise, including impingement on personal freedom and the perceived loss of the wilderness

experience. Nevertheless, for wilderness to be wild it must be sustained as a healthy ecosystem, and to be enjoyed as wild it must be free from overuse.

Virtually all four recommended actions concerning capacity and concentrated use call for involvement on the part of researchers. The first recommendation was to set specific wilderness management objectives, giving priority to alleviating areas of concentrated overuse and including "limits of acceptable change" or similar principles as integral components of wilderness management plans. The limits of acceptable change concept is an innovative and promising approach to address the problems of capacities and overuse (Stankey and others 1985). However, assistance is needed from the research community to identify the best indicators of wilderness resource conditions to monitor, to delineate the sampling and measurement techniques, to define the interrelatedness of the systems we are monitoring, and to determine avenues for meaningful public involvement.

The second recommendation was to test varied approaches to resource rehabilitation and alleviation of overuse, and report evaluations of those approaches. There is a burgeoning, almost grassroots, effort in parks and wilderness areas to rehabilitate the impacts of past overuse. Yet research into the most effective techniques, the most suitable species, the most effective propagation and reintroduction methods, and the effects of climatic and site conditions is still lacking (Cole and Schreiner 1981). Many managers are making valiant attempts, yet often they have little concrete guidance from scientists. This is an important area of investigation that demands further attention from researchers.

Not only do managers sometimes lack scientific information, they often find it difficult to locate and retrieve what does exist. Thus, the third recommendation was to establish a computer library (or bulletin board) of wilderness training; education programs; and management techniques, such as handling concentrated use, data collection, monitoring, and rehabilitation. It must be easily accessible to all agencies, researchers, and educators. We see computers not as a panacea, but rather call for their information processing capabilities to be put to work and made readily available to serve wilderness management.

The fourth recommendation was to conduct research and development to establish procedures to modify undesirable behavior with the least impact on the quality of the visitor's wilderness experience. Many workshop participants recognized that the biggest problem facing wilderness management was the first three letters—man. Education; information; permits; rationing; location of campsites, trails, and trailheads; and regulating method of travel, equipment, group size, and time and length of visit are a few of the procedures managers have at their disposal to affect behavior. Researchers and managers should work together to test and refine these and other methods to provide the best management tools. Clearly, the problems of capacity and concentrated use provide fertile grounds for research.

INTERAGENCY COORDINATION AND CONSISTENCY

Coordination and consistency within as well as among agencies managing wilderness were called for by the workshop participants and the public at large during the comment period. Recommendations to accomplish this were to continue to develop and improve interagency wilderness management training programs and to coordinate communication among agencies on wilderness management.

Wilderness research can play a role by cutting across jurisdictional lines. We should share and contribute to the training of managers, regardless of their agency affiliation. Perhaps researchers can fulfill the role of impartial purveyors of useful information and thus help bridge the gap between the management agencies to the betterment of the National Wilderness Preservation System.

WILDERNESS MANAGEMENT PRACTICES

The fifth and final category of management issues includes wilderness management practices. Wilderness by its very nature requires a different approach than lands managed for other purposes, or even specifically for recreation. The perpetuation of the wilderness resource and its natural ecological processes must come first. Wilderness management also requires attention to what is happening around its boundaries and often extensively beyond them as well.

Two actions were recommended that require the expertise and support of research. The first is to identify, monitor, and publicly report internal and external threats to wilderness values from whatever source, whether overuse, acid rain, other forms of degraded air quality, or visual or sound impairments. The public has a right and a need to know of conditions that may threaten the integrity of their wilderness resources. Impartial research and the public reporting of the same in the long run will produce a more concerned, informed, and broad-based public constituency that will benefit wilderness management everywhere.

A second recommendation was to manage indigenous plant and animal communities to sustain natural processes, assuring that levels of human use are compatible rather than detrimental, with emphasis on preserving endangered and threatened species, as required by law. Once again, the emphasis is to maintain and perpetuate natural processes, a task that demands continued and increased attention from research.

BASIC RESEARCH NEEDS

Let me conclude by emphasizing that our research must not be constrained just to management or applied research. There exists a pressing need for basic research if we are to understand the natural processes that we are mandated to perpetuate. Research on plant and

animal species (including humans), on the effects of physical and geological processes, on cumulative effects, on the dynamics of natural change, and on the functioning of interrelated ecosystems is vital if we ever hope to learn to manage and preserve and perpetuate our wilderness resource.

My point should be clear by now. A host of issues confronts wilderness management, and solving many of these issues will require the attention and best work of researchers. The National Wilderness Management Workshop focused attention on the necessity of "taking care of what we've got." It also amply illustrated that we now have the need for this National Wilderness Research Conference to lead the way in "learning to preserve" the most priceless resource of all—wilderness.

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A FRAMEWORK FOR WILDERNESS ASSESSMENT AND RESEARCH

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ABSTRACT

A panel of key scholars has provided guidance in formulating a detailed outline of the 1989 Renewable Resources Planning Act Assessment of Wilderness. This outline includes recreational and nonrecreational wilderness values and uses and considers a broad definition of the wilderness resource. Embedded within this outline are questions which serve to identify the data, analyses, and research needed to complete the RPA and future assessments. We conclude this paper with identification of six critical research missions. These missions pertain to benefits, vicarious values, resource evaluation, modeling, recreational capacity, use interactions, and management and policy relationships. Ongoing research is needed to address these issue-derived missions so that the information and methodology voids that exist now need not be barriers to improving future wilderness assessments.

INTRODUCTION

The 1974 Forest and Rangeland Renewable Resources Planning Act (RPA) requires comprehensive national assessments of the forest and range resource base in the United States at 10-year intervals. The last such RPA assessment was completed in 1979.

Wilderness is an important component of the resource base as it is studied in the RPA assessment. In planning the 1989 Assessment, the Forest Service is seeking to improve the data, methods, models, and body of knowledge applied to describing, analyzing, understanding, and predicting the resource supply and demand situation. For wilderness, improvement of data on the users and uses of wilderness, its values and benefits, condition of the wilderness resource, interactions with other resource uses, and projections of future conditions and demands are being given close attention. Unless otherwise stated, our reference to wilderness in this paper will be limited to areas in the National Wilderness Preservation System as well as areas in State and private systems. By this definition wilderness includes roadless areas designated as wilderness by the owner and managed to protect the area's natural attributes while prohibiting mechanized and extractive uses, except as covered by grandfather clauses.

To develop an approach to this wilderness assessment, a panel of key scholars in the wilderness field was organized under the guidance of the Forest Service's RPA Washington Office. This panel has helped us to outline the needed assessment report and to identify the key questions, data, and analyses needed to assess the demand for and supply of wilderness in the United States. This outline and its inclusive questions will guide the 1989 Assessment. With the panel's help, we have gone beyond the 1989 Assessment and have identified data, analyses, and research needed for future wilderness assessments and policy deliberations.

This paper serves as a starting point for a problem analysis and plan for wilderness assessments and related research. While it focuses on existing data, analyses, and state of knowledge, it also describes the additional information and research needed to improve future assessments.

A national assessment should comprehensively describe and analyze demands, supplies, and social, economic, and environmental relationships with wilderness resources in an unbiased and objective manner. Interpretations of the results should be guided by the data, methods, and expertise employed; more so than by political or personal concerns. The goal is to produce a highly credible and unbiased RPA Assessment. To do so we will seek continued involvement and review by key scientists from universities and agencies. These individuals can contribute the ideas, concepts, analytical methods and models, data, and interpretations needed for the 1989 RPA, as well as future assessments.

The structure of the next section of this paper generally follows the outline intended for organizing the data and analyses for all the resources addressed by the RPA Forest and Range Assessment. Under each outline element are listed the major technical questions thus far identified. Most of these questions go beyond the problem of lack of data. Known data bases pertaining to demand, supply, and management of wilderness have been identified and listed. There are sure to be other relevant questions and data bases that should be included. At this symposium we seek to learn, as we have learned from the May 1985 Eastern Wilderness Conference held in Nacogdoches, TX. Questions and data pertaining not only to the National Wilderness Preservation System, but also to roadless areas under study and areas designated as wilderness by States or private entities must be included.

PROPOSED FRAMEWORK FOR A NATIONAL ASSESSMENT OF WILDERNESS

Here we outline our concept of the data and analyses needed for a comprehensive assessment of wilderness. Equally involved in conceptualizing this outline were Dr. Glenn Haas, Associate Professor, Colorado State University, and Dr. John Hendee (then with the Forest Service), Dean, School of Forest, Wildlife and Range Sciences, University of Idaho. This concept will not necessarily coincide completely with the outline and approach that are finally adopted for the RPA Assessment.

Ours is certain to be somewhat more comprehensive than the final assessment for RPA, because it serves additional purposes. One of these purposes is to stimulate research that would lead to improvements in our abilities to assess the demand for and supply of wilderness. Embedded within the outline that follows are questions which, as yet, have not been satisfactorily answered. These questions will form the basis for a proposed research agenda in a later section. We request comment and suggestions to refine this agenda.

The RPA Assessment will treat the recreational aspects of wilderness in the outdoor recreation assessment volume, the water aspects of wilderness in the water volume, and other nonrecreational aspects in the other relevant RPA resource assessment volumes. A national colloquium will be held in September 1987 to highlight the state of the art pertaining to the nonrecreational uses and values of wilderness.

CONCEPTUAL OUTLINE

A. Introduction

1. History, major issues, and trends in wilderness allocation, management, research, and education
2. Organization of the wilderness analysis

(Comment: This section is proposed to include identification of current issues that should guide analysis and bring focus to relevant program implications. A principal source will be the listing of issue priorities generated at the National Wilderness Management Workshop, University of Idaho, October 1983.)

Q. Do systems or models exist to guide or form the basis for a national wilderness assessment, such as Limits of Acceptable Change or the Recreation Opportunity Spectrum?

Q. What are the critical current issues in wilderness management, protection, and allocation which should drive a national wilderness assessment?

Q. How localized (disaggregated) do demand and supply analyses for a nationwide assessment of wilderness need to be—for example, by area, region within a State, region within country, national?

Q. How does the concept of wilderness fit with other preservation concerns such as critical faunal and floral habitat and biological reserves?

Q. How does U.S. wilderness fit within the global context of wilderness?

B. Prospective Trends in Demand

Q. How can trends in uses, demands, and values of wilderness best be expressed, measured, and projected?

Q. What are the relationships, tradeoffs, and relative trends among recreational, educational, scientific, human developmental, environmental preservation, and ecosystem representation demands for wilderness?

1. Onsite Recreational Demand

   a. Trends in participation and percentage of population participating

   Q. What surrogate measures of wilderness demand can be identified and what limits of interpretation should be imposed?

   Q. How can trends in use of newly designated areas be estimated given that historic records do not exist?

   Q. Are users of wilderness areas changing and what is the proportion of new users?

   Q. What is the relationship between wilderness education programs and the level and type of use of wilderness?

   Q. What is the extent and character of recreational use of non-System wilderness and how is this changing?

   b. Projections of Participation Changes by Region

   Q. What are the relationships between demographic, socioeconomic, geographic, and population trends and changes in uses and values of wilderness?

   c. Visitor Attitudes and Satisfactions

   Q. Which activities and experiences are dependent on designated wilderness, and can those which are not dependent be better provided elsewhere?

   Q. To what extent does wildlife observation supplement wilderness visitation experiences and satisfactions?

   Q. How does visual evidence of human use affect visitor satisfactions?

   d. Trends and Projections of Indices of the Recreational Values of Wilderness

   Q. What set of factors determines and can be used for projecting recreational values of wilderness?

2. Extent of Scientific Use

   Q. How does wilderness preservation benefit science and how can science benefits be measured?

3. Educational and Personal Development Uses

   Q. What are the nature of and trends in growth of human resource programs and uses of wilderness, for example, Rights of Passage, Vision Quest, Leadership Schools, Boy Scouts?

   Q. How essential are wilderness settings to the success of human resource programs?

4. Ecosystem Representation and Environmental Preservation Values

   Q. How can preservation uses and values be expressed so that they can be compared with other uses?

   a. Noncomforming uses (minerals, water, grazing, subsistence uses, etc.)

Q. What are the extent and effect of extractive uses on long-term ecosystem dynamics?

5. Total Demand and Relative Rates of Change in the Components of Total Demand

Q. Can a composite demand measure, including the recreational, scientific, and other wilderness demands, be structured and estimated?

C. The Resource

Q. Is there a model that identifies the factors, resources, and relationships critical to assessing wilderness resources? For example, do Limits of Acceptable Change, the Recreation Opportunity Spectrum, or the Ecoregion System provide adequate models?

(Note: Whatever system is selected, it must be broadly reflective of the many values and management concerns of wilderness.)

1. The National Wilderness Preservation System by Agency and Region

a. Acreage and condition of designated and study areas

Q. How can the quantity and condition of the wilderness resource be best expressed to represent different concepts of wilderness values?

Q. What methodology, models, and techniques exist for assessing the visual, experiential, and ecological quality of wilderness?

b. Recreation trails, access heads, motorized access, camps, and shelters

Q. What sources of data are available for quantifying recreational facilities and developments in wilderness areas?

c. Ecosystem representation

(1) Acres by ecosystem and adequacy of representation

Q. What are the critical ecosystems that could be represented by wilderness, and to what extent are these ecosystems currently represented?

Q. How can the adequacy of ecosystem representation best be measured?

(2) Critical threatened and endangered plant and animal habitat

Q. To what extent do wilderness areas serve as enclaves for protecting certain plant and wildlife species, for example, mountain caribou, condors?

d. Private inholdings

e. Changes in legislative definition

Q. Are the definitions of suitability and standards of management of new wilderness areas different from the original legislation, and can these differences be systematically described?

2. Nonsystem Areas With Recreation Experience Substitute Potential

Q. How can roadless areas that can provide substitute recreational experiences be identified and evaluated for their potential substitution for designated wilderness?

3. State and Private Wilderness Systems and Areas

Q. In which States do State wilderness systems exist, and how much and what types of areas exist?

Q. To what degree do State and private wilderness areas provide wilderness benefits, and to what extent do these complement the benefits provided by the National System?

4. Comparison of Management Philosophies and Policies Among Federal Agencies, States, and Private Concerns

5. Prospective Changes in Wilderness Designations

a. Study and other roadless areas by agency, region, and ecosystem

Q. What assumptions and rationales are necessary as bases for projecting prospective trends in wilderness allocations?

D. Evaluation of the Relative Changes in Wilderness Demand and Supply

Q. How can values and future levels of wilderness recreation demand best be estimated?

Q. What criteria or standards are appropriate for defining optimum wilderness allocation and management for recreational and nonrecreational uses?

Q. How can nonrecreational demand and supply comparisons be formulated and carried out?

1. Recreation Visitor Days (RVD's) of Use Versus RVD's of Capacity Over Time

2. Projections of Wilderness Recreation Supply and Demand

3. Values per RVD of Wilderness Recreation by Region

4. Option, Existence, and Bequest Values of Wilderness

Q. Does membership and support of wilderness advocacy organizations provide a measure of these demands and values?

5. Trend Projection of Nonrecreational Wilderness Demand

E. Implications of Demand-Supply Comparisons

1. Social

Q. Do wilderness recreation experiences contribute to expressions of personal and social well being, such as increased productivity?

Q. To what extent does wilderness serve as a rallying point for conservation concerns and how then does wilderness concern affect the status and conservation of other natural resources?

a. Distribution of opportunities for wilderness recreation relative to distribution of population

Q. How can opportunities for similar experiences in nondesignated areas be considered in weighing the relative availabilities of wilderness recreation opportunities?

b. Possible discriminatory effects of supply-demand situation, including regulatory changes

Q. Are some wilderness uses and users being displaced, and for what reasons?

Q. To what extent are nonrecreational uses affected by regulations and practices that apply to recreation?

c. Social and cultural values of subsistence uses

Q. What data exist to describe subsistence uses and the interaction of these uses with other uses and values of wilderness?

2. Economic

Q. What are the existing estimates and methodologies for estimating direct and secondary economic consequences of wilderness?

(Comment: The current Public Area Recreation Visitors Survey incorporated a separate sample of NFS wilderness areas which will yield recreational use demand functions and profiles of visitor expenditures in local economies.)

a. Indirect benefits and opportunity costs of increased wilderness allocation

Q. What is the nature and magnitude of wildlife, water, range, timber, and other benefits and opportunity costs associated with increased wilderness allocation?

Q. How can indirect benefits and opportunity costs be estimated?

b. Economic impacts of projected changes in wilderness recreational use and supply

Q. To what extent and how are local economies affected by wilderness allocations and policies?

c. Potential impacts of wilderness recreation user fees

d. Contribution of subsistence uses to economic well being of rural communities

e. Management cost implications of evolving legislative definition of wilderness, including air and water quality standards and inclusion of smaller areas

3. Environmental

a. Air and water quality implications in surrounding areas resulting from adherence to wilderness standards

b. Forest insect and disease spread potential from protected wilderness areas

c. Interactions between uses of designated wilderness and surrounding lands

Q. How do designated wilderness areas and the land and land uses surrounding these areas interact in terms of economic, developmental, and environmental changes?

F. Opportunities to Improve Wilderness Management

(Comment: These opportunities will be identified in the analysis in sections A-E. The peer panel of experts, which convened at Nacogdoches and at Fort Collins, provided ideas, proposed strategies, identified data and information sources, and provided review on such questions as the relationships or tradeoffs between increased management of existing wilderness and new allocations in producing needed wilderness outputs.)

Q. What are the environmental protection and management costs associated with full implementation of wilderness standards as defined by legislation?

Q. What is the relationship or tradeoff between changes in wilderness allocations, wilderness management, and the values produced?

Q. Is it possible that primitive recreation experiences can be provided more efficiently in nondesignated, semiprimitive areas where greater flexibility in management is possible?

Q. What is the relationship between the quality of wilderness experiences and intensity of management and regulation?

Q. What are the more promising opportunities to improve the management of wilderness, and what are the principal obstacles to implementing these improvements?

Q. How should wilderness user fees be applied? What are the costs of alternative fee collection strategies? Can "peak pricing" be implemented? What portion of social costs should be recovered through fees?

Q. How can increased benefits from reduced congestion on existing sites or trails be accounted for in management and allocation decisions?

In the final phases of the RPA Assessment of wilderness, we will identify and describe obstacles to achievement of wilderness objectives. Such obstacles as rising costs, impinging external environmental threats, and competing resource demands will be considered. From the analysis of these potential obstacles will come implications for development of management, research, and assistance programs. These implications will be reported to the Forest Service, the U.S. Department of Agriculture Secretary's Office, the Office of Management and Budget, and the Congress for consideration of agency budgets, programs, and policies.

CRITICAL ISSUES AND THE NEED FOR ASSESSMENT RESEARCH

The issues and questions about wilderness can be grouped into two categories: (1) those pertaining to allocation, and (2) those pertaining to policy and management. Allocational questions address how much, what kind, and where more (or less) designated wilderness is needed. Policy and management questions pertain mostly to the

guidelines, rules, and practices applied to already designated wilderness. One of the more important questions fits neither category: What is the relationship between more or less allocation and more or less management in meeting wilderness demands?

Most of the questions identified in the preceding outline have to do with policy and management. Among these, we will concentrate mainly on policy questions because policy making is the major reason for conducting a national assessment. Issues and research pertaining mostly to management have been addressed in the publications resulting from the National Wilderness Management Workshop (Moscow, ID, October 1983).

Among policy-related questions are those that are researchable and those that are not because their answers must be derived through political or other social choices. Below we have identified the policy-oriented questions that we perceive to be researchable and, therefore, which define a wilderness assessment research agenda. Identification of researchable questions is based on two criteria:

1. The question can be addressed and information provided without having to make a value judgment in terms of "what should be."
2. The question asks how to measure, identify, or predict some attribute of wilderness demand or supply (methodology); it seeks to portray meanings, orderings, changes, or differences that are relevant (description); or it addresses a need for a meaningful framework for abstracting, understanding, and predicting wilderness resource or user behavior changes (theory development).

The priority we have placed upon the researchable questions reflects: (1) the immediacy of the need to know because the issue addressed is currently pressing, and (2) the importance of developing the method, description, or theory as an essential ingredient for improving wilderness assessment capability.

Following in highly abstract form are our perceptions of the six highest priority missions for wilderness assessment research. An essential first step in undertaking such a research effort must be to provide a model, system, or definitional framework within which to comprehensively consider and analyze the values, benefits, management concerns, and resource attributes of wilderness.

Benefits.—Conceptualize, test, and specify the units of measure and the methods of measuring and projecting the experiential attributes, values, and benefits of wilderness in terms suitable for policy evaluation and decisionmaking.

Vicarious Values.—Provide definitions and methods for estimating and develop estimates of the existence, option, and bequest values of wilderness.

Resources.—Develop a wilderness resource evaluation model that (1) represents the multiple resource dimensions relevant to the various human values attached to wilderness (recreational and nonrecreational), and (2) represents the biological and physical properties and interactions of wilderness.

Recreational Capacity.—Develop efficient measures of the recreational capacity and of the interactions of recreational use with the natural system dynamics of wilderness.

Interactions.—Evaluate the interaction of wilderness with outside-of-wilderness air, water, soil, faunal, floral, and social conditions and changes.

Management-Policy Relationships.—Estimate and provide guidelines for evaluating tradeoffs between management and allocation for meeting changing demands for wilderness.

It is clear that the contents of the above six research missions are highly interdependent. They all deal with the same designated or other roadless areas. Obviously, then, research applied to these missions must be highly coordinated within a common framework and definitional structure. The RPA Assessment seems to provide the early stages of a feasible framework. RPA also provides a targeted end use for this policy-oriented wilderness research. Symbiotically, the RPA Wilderness Assessment can benefit not only from the data and analyses that would result from this research agenda, but also from the evolution of understanding and resultant improvements in an assessment framework that would flow from increased understanding. Thus, it is further obvious that benefits may be realized with a solid connection between the Wilderness Assessment process and a coordinated policy research program.

NEED FOR CONTINUOUS ASSESSMENT AND RESEARCH

The wilderness assessment has three main components: (1) examination of the status of and changes in demands and supplies of wilderness resources; (2) projection of future changes and the social, economic, and environmental consequences of those changes; and (3) interpretation of the implications of the current and probable future situations for legislation, policy, and management. Research provides the methods and data for measuring change and the theory for interpreting its implications. The process of change is continuous, so continuing research is needed to incorporate new knowledge into our accumulated body of knowledge and methods. New knowledge, beyond that for periodic assessments, is needed to meet the needs of decisionmakers as they face continuously unfolding developments. One outstanding example is the need for data and methods to support the implementation and monitoring phases of the land management planning mandated for National Forests. Previous land planning work has been hampered by voids in data and methods.

The need for ongoing wilderness policy research, then, is driven not only by the need for a periodic snapshot of the demand and supply situation (an assessment report) but also by the continuing flow of questions and issues wrought by a society in flux. Over our short history of intensive, one-at-a-time peeks at where we are (for example, the Outdoor Recreation Resources Review Commission of 1960, the Public Land Law Review Commission of 1970, the Outdoor Recreation Policy Review Group of 1982, and the President's Commission on Americans Outdoors of 1985), it has become painfully obvious that we need a continuous assessment and research process. Each time we stop to take this peek, we discover and bemoan

the lack of data, methods, and forecasts. Each time we vow to do something about it, so that next time we will be prepared to satisfy needs and answer questions.

The President's Commission on Americans Outdoors is likely to choose not to examine in detail the demand and supply situation in the United States simply because it does not have the time or resources to generate the information. The necessary information certainly does not already exist. Thus far, each time a new need has surfaced, we have suffered from the void of an ongoing assessment and research program that would maintain and update continuously the data, methods, and analyses needed to make fully informed judgments.

The current organization of the Forest Service's RPA Assessment could be the beginning of a more comprehensive ongoing partnership between wilderness research and policy evaluation. Leading wilderness researchers have been asked to review a proposed outline of analysis plans and needs. They have shared questions believed to represent significant barriers to carrying out the intended analyses. Because the upcoming RPA Wilderness Assessment is housed within a research project at Athens, GA, a vehicle exists for pursuing research before, during, and after the assessment. Involvement of key researchers provides a tap to the most current knowledge and technology. It provides an interface with the expertise needed to address voids in knowledge and technology. It is our hope that something like the current marriage between the RPA Assessment and research can be continued so that we can avoid the costly stop-start mode so typical of regional and national planning and assessment.

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Section 2. State-of-Knowledge for Wilderness Resource Research

THE ROLE OF FIRE IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

Bruce M. Kilgore

ABSTRACT

Literature from the United States, Canada, and Australia is reviewed to summarize knowledge concerning fire history, effects of fire, fire behavior, what is "natural," the role of Indian burning, the role of prescribed fires, effects on wildlife, insects and disease, and nutrient cycling, and the role of stand replacement fires in wilderness ecosystems. Opportunities and priorities for further study on the role of fire in wilderness are suggested. Unresolved questions and problems are presented.

INTRODUCTION

Research on the role of fire in natural ecosystems and, specifically, the impacts of fire on wilderness values, has been an important part of fire research in the past few decades. Pyne (1985) feels that wilderness fire "reoriented fire research into biological topics and fire effects at large, both ecological and economic." It also compelled a fundamental separation of wildland fires into two broad categories, wild and prescribed.

This paper will attempt to summarize what we know about (1) the fire history of various wilderness ecosystems; (2) fire effects in these wilderness ecosystems; (3) fire behavior in wilderness ecosystems; and (4) "wilderness fire," involving such special philosophical concerns as (a) what is "natural;" (b) the role of Indian burning; (c) the role of planned or scheduled prescribed fires; and (d) the role of high-intensity, stand-replacing fires in these natural ecosystems.

Conceptually, the role of fire in all ecosystems managed for natural values—such as research natural areas (Kilgore 1984)—is of concern. In practice, the dominant management interest and primary research information to date come from the large wilderness units in National Forests and National Parks where impacts from adjacent managed vegetation are less. Hence, I will tend to focus discussion primarily on these areas, while attempting to discuss principles and insights that will be meaningful in any ecosystem managed for natural values.

I will rely primarily on data from literature published in the United States, Australia, and Canada, because, as Parsons (1981) noted, with the exception of "Australia and parts of Africa, where prescribed burning . . . has been utilized . . . to perpetuate native communities for many years (Hodgson 1967; Phillips 1974), there is little evidence of other countries showing interest [in using fire to maintain natural ecosystems]." Emphasis will be on the effects of fire on resources, with only minor reference to relationships involving human use of wilderness, such as air quality and the impacts of fire on visitor experiences. While solid data from any source have been sought, there tends to be a geographical emphasis on the Western United States, largely because much of the primary wilderness resource and research results tend to focus there.

The Role of Philosophy and Policy

Elements of philosophy and policy have considerably influenced research on wilderness fire. Factual data on the role of fire in various ecosystems, involving both fire history and fire effects, provided the ecological and theoretical basis for fire management (Kilgore 1976) and for research on wilderness fire. The need for additional research on the "natural" role of fire and philosophical support for accepting what is "natural" in wilderness ecosystems were emphasized to managers and the public by the popular (sometimes almost poetic) and widely recognized ecological statements of three men—one a manager, the other two scientists—who had broad vision and philosophical-ecological bent. These men were: (1) Robert Marshall, one of the original founders of The Wilderness Society (see Winter 1984 issue of **Wilderness**, quarterly publication of The Wilderness Society); (2) Aldo Leopold, the father of game management, who was closely associated with Marshall in establishing the first National Forest Wilderness—the Gila in New Mexico (Leopold 1921, 1949); and (3) A. Starker Leopold, one of Aldo's sons, who was chairman of the committee that prepared the widely quoted Leopold Report of 1963 (Leopold and others 1963). That report made major recommendations for revision of National Park Service resource management policy, including fire management. Impetus for work done by National Park Service scientists (and by other agencies as well) was provided by the Leopold Report. For the Park Service, this was supplemented by direct consultation with Starker Leopold, who served briefly as its chief scientist. His personal involvement was extremely important—both scientifically and politically—in implementing the first natural fire zones in Sequoia-Kings Canyon National Parks in 1968 and in gaining support for initiating early research on the impacts of fire in these wilderness zones.

GENERAL EVOLUTION OF RESEARCH ON FIRE IN WILDERNESS

In reacting to the concept of wilderness fire research, C. E. Van Wagner once asked, "Is this a new division of fire research in general? Where do the more traditional features of fire behavior and the biological results of fire

effects fit?" (Van Wagner, personal communication 1985). My answer is that if wilderness fire research is restricted to direct, management-oriented studies, then it becomes very narrow and somewhat isolated from the data most needed to make it useful. If not so restricted, it becomes very broad and includes much of fire effects research in general. For the purposes of this discussion, therefore, wilderness fire research includes (1) studies of fire history, behavior, and effects that apply to ecosystems most strongly involved with wilderness, parks, and other natural areas; and (2) special studies to determine what is "natural," involving both philosophical and policy matters as these relate to Indian burning, agency-ignited fires, the role of high-intensity, stand-replacing fires, and the impact of fire suppression on fuel accumulation and forest structure.

Shifting Focus of Fire Research

Initial emphasis in fire effects research was on how to improve fire suppression techniques and on case studies of damage caused by fire in given ecosystems (Show and Kotok 1924, 1930). Most of these studies were not carried out in natural systems. Federal and State land management agencies were so committed to total exclusion of fire that there was "reluctance to promote research or release results which seemed to jeopardize success" of other agency fire projects such as fire suppression (Schiff 1962).

This early emphasis on the negative aspects of fire—or fire damage—was gradually changed by the work of such early plant ecologists as Clements, Cowles, Hall, Ramaley, and Cooper (Bock 1976) working largely with lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*). In addition, a group of fire scientists in the South known as the "Dixie Pioneers" (Komarek 1973) challenged the concept that all fires are bad. This group of four men included a forester (Chapman 1912), a botanist (Harper 1913), an animal husbandman (Greene 1931), a wildlife scientist (Stoddard 1935), and several Forest Service scientists from southern experiment stations (Heyward and Barnette 1934). In combination, the work of these southern fire scientists showed that prescribed burning could be beneficial to longleaf pine, cattle, and quail without damaging the chemical composition of forest soils in the region.

Western counterparts to these southern scientists included two foresters with the Bureau of Indian Affairs (BIA) and a forestry professor in California. The combined ponderosa pine research and experimental management efforts of Harold Weaver (1943) in Washington, Oregon, and Arizona, Harry Kallander in Arizona, and Harold Biswell of the University of California at Berkeley led to three conclusions: (1) that ponderosa pine forests had developed in nature with frequent low-intensity fires; (2) that fire exclusion has resulted in extreme fire hazards today; and (3) that prescribed burning by means of low-intensity fires can reduce fuels while simulating other ecological impacts of natural burning (Biswell 1967). Early research on the role of fire in Everglades National Park in Florida (Robertson 1953) and the Boundary Waters Canoe Area in Minnesota (Heinselman 1973) illustrated the importance of natural fire questions beyond western wilderness. More recently, natural fire management programs implemented in National Parks and National Forest Wildernesses in the West have led to research results that further our understanding of the role of fire in natural ecosystems (Kilgore and Briggs 1972; Kilgore 1973a; Mutch 1974; Despain and Sellers 1977; van Wagtendonk 1978; Parsons and DeBenedetti 1979).

Research questions initially began as some form of "How can we best suppress fires on all lands, including parks and wilderness?" This gradually changed to such specific questions as "Does fire always cause soil erosion and always harm wildlife?" Somewhere in the late 1950's and early 1960's, we may have switched from a "fire is bad" to a "fire is good" approach before moving to the more objective question, "How does fire affect various resources (wildlife, soil, water, and vegetation)?" Fire is not always good for wildlife or plants. Some papers seem to imply that high plant/animal diversity in early succession means disturbance is good and old stands with lower diversity are decadent. As applied to wilderness, fire effects that best mimic the natural ecosystem are good—they may be from either low or high intensity, frequent or very infrequent fires.

With the advent of the Leopold Report (Leopold and others 1963), the focus shifted rapidly to the question of whether fire could be allowed to burn in wilderness and park lands without damaging the resource. The current research question has become "How can we best restore fire to its natural role in wilderness?" Subquestions involved include: (1) What is "natural?" (Kilgore 1985b); (2) what changes were caused by fire suppression? (van Wagtendonk 1985; Habeck 1985; Brown 1985); (3) do we need to use human-ignited prescribed fires to restore or maintain a semblance of naturalness? (Kilgore 1982; Worf 1985; Lucas 1985; Kilgore 1985a); and (4) how precise do we need to be in restoring vegetation in parks and wilderness? (Bonnicksen 1985; Bancroft and others 1985; Parsons and others 1986; Bonnicksen and Stone in press).

Development of Theoretical Structure of Wilderness Fire Research

A background in basic ecological concepts is necessary to understand how wilderness ecosystems operate (Franklin 1978). We need knowledge of the composition, processes, and structure of forested and other wilderness ecosystems before we can study wilderness fire.

Fire Dependence.—One of the most fundamental concepts, on which all wilderness fire research is based, is that the natural state of most ecosystems in wilderness, parks, and other natural areas is fire dependent. The early work of Clements (1910) in lodgepole pine, Maissurow (1935) in white pine (*Pinus monticola*), Weaver (1943) in ponderosa pine, Robertson (1953) in subclimax slash pine (*Pinus elliotti*) of Everglades National Park, Spurr (1954) in forests of Itasca State Park in Minnesota, and Cooper (1961) in ponderosa pine forests in Arizona helped strengthen this understanding. Ahlgren and Ahlgren (1960) synthesized much of the

general ecological effects literature available prior to 1960. Hartesveldt and his colleagues at San Jose State College in California conducted important studies on the role of fire in giant sequoia (*Sequoiadendron giganteum*) groves in Sequoia-Kings Canyon and Yosemite National Parks, California (Hartesveldt 1964; Hartesveldt and Harvey 1967; Harvey and others 1980). At the same time, studies in the sequoia-mixed conifer forest were being carried out by Biswell and Kilgore (Biswell and others 1966, 1968; Kilgore and Biswell 1971; Kilgore 1973a,b). All of these studies confirmed the dependence of these ecosystems on a regular recurrence of fire.

Mutch's 1970 paper in **Ecology** was an important conceptual contribution. He hypothesized that, "Plant communities may be ignited accidentally or randomly, but the character of burning is not random. . . . Fire-dependent plant communities burn more readily than nonfire-dependent communities because natural selection has favored development of characteristics that make them more flammable." The significance of this hypothesis is tremendous. At the risk of being anthropomorphic, ponderosa pine and similar fire-dependent ecosystems, in effect, "make sure they burn" by dropping highly flammable dry pine needles at the base of the parent tree annually; then when fire occurs, pines gain a competitive advantage over other species that occur in mixed conifer communities.

Fire performs a number of roles in most ecosystems or plant communities. These can be summarized in various ways, but the following eight statements paraphrase the roles previously suggested by Kilgore (1972, 1973b), Wright and Heinselman (1973), and Heinselman (1978):

1. Fire controls plant community composition.
2. Fire terminates and renews succession.
3. Fire controls the scale of vegetation mosaic.
4. Fire regulates fuel accumulations.
5. Fire controls nutrient cycles and energy flows.
6. Fire impacts wildlife habitat.
7. Fire interacts with insects and diseases.
8. Fire impacts productivity, diversity, and stability of the ecosystem.

From 1962 to 1976, the annual **Proceedings of the Tall Timbers Fire Ecology Conference** provided an important forum for exchange of ecological knowledge about such effects of fire in fire-dependent ecosystems. Since 1970, an ever-increasing number of research reports on the fire ecology of various vegetation types have been published. Many have been summarized in books, review articles, or annotated bibliographies (Wright and Heinselman 1973; Kozlowski and Ahlgren 1974; Baker 1975; Heinselman 1978; Mooney and others 1981; Wright and Bailey 1982). A growing number of symposia have been held in various parts of the United States, Australia, and Canada, where scientists and managers have discussed the role of fire in various geographic areas and vegetation types; proceedings have been published summarizing these ideas. Most recent among these are the symposia on mediterranean-climate ecosystems (Mooney and Conrad 1977; Conrad and Oechel 1982); Australia (Gill and others 1981); and wilderness, parks, and other natural areas (Lotan and others 1985).

Fire History.—A second fundamental idea in the theoretical structure of wilderness fire research is fire history. By fire history, we mean the frequency (interval between fires), intensity or severity, and the sizes and seasons of past fires in a given ecosystem. Study of fire history has come to be almost synonymous with study of fire scars found in the radial growth patterns of both softwood and hardwood tree species. Use of aerial photographs for mapping stands arising after severe fires and increment core dating of fire-origin age classes on the ground are other means of obtaining fire history information, particularly in forests in which stand-replacing fires are common. As an example, in his monumental work in the Boundary Waters Canoe Area, Heinselman (1973) determined detailed stand origin and fire year maps and individual fire year dates for a 1-million-acre study area. His work included careful interpretation of fire history since 1595, the role of climatic and physiographic factors, detailed discussions of paleoecological evidence of fire, ignition sources and fuel interactions, and succession, diversity, and stability as they relate to fire. Heinselman also established the concept of "natural fire rotation." This concept is similar to Van Wagner's "fire cycle" (personal communication 1978) and Tande's (1979) "fire return interval." The most complete current bibliography of fire history research (Mastroguiseppe and others 1983) contains 520 references.

Fire Regimes.—The third major concept of wilderness fire research is fire regimes, defined by Heinselman (1985) as "the kind of fire activity that characterizes a specific region." We classify ecosystems into varying fire regimes made up of factors such as (1) fire type and intensity (distinguishing crown fires or severe surface fires from low-intensity surface fires); (2) frequency or return intervals typical for the vegetation type or geographic unit; (3) size of area burned in a typical ecologically significant fire; (4) typical season of burning; (5) pattern of burn; and (6) severity or depth of burn (Gill 1973; Heinselman 1978, 1981; Methven 1978; Sando 1978; Keeley 1981). The first two factors are most important in the fire regimes suggested by Heinselman (1978, 1981), Sando (1978), and Kilgore (1981).

Pyne (1984) sees fire regime as an "amorphous [and] intuitive rather than rigorous . . . concept which seeks to reconcile the physical nature of fire with the biological context within which it burns." While it attempts a great deal in synthesizing broad ecological and physical principles into a few categories, the fire regime concept does lend a semblance of order to an otherwise very confusing, contradictory, and voluminous literature of fire ecology that tends to be highly specific and descriptive only of a particular fire at a particular time and site (Pyne 1984).

Development of Wilderness Fire Research Methods

Broadly speaking, fire research can either (1) follow a process of developing theoretical models of wildland fire interactions with vegetation and fuels in various ecosystems and then checking how well such models can predict real-world situations; or (2) use a more empirical approach, emphasizing observations and measurements

of real-life interactions among fire, vegetation, and fuels, with all their complexity. While there are hundreds of physical, biological, and socioeconomic models related to wildland fire management to date (Simard 1981b), much is lacking in the way of theory, data, and experience in the short history of modeling in fire management. A number of models and their related support systems (Rothermel 1980) have been developed in the fire behavior field that appear to be extremely useful in representing fuels for estimating fire behavior, but relatively few models try to integrate changes in vegetation and fuels over time with fire frequency and intensity. All have integrated the theoretical and empirical approaches due to lack of data.

Examples of these more complex models are FYRCYL (van Wagtendonk 1972), a computer model of the natural fire cycle that simulates fuel accumulations, lightning fires, and subsequent fuel reductions in frequent, low-intensity surface fire regimes in the Sierra Nevada; FORFLOR (Agee 1973), which was developed to investigate erosion hazards caused by lightning ignitions; a structural model developed by Bonnicksen and Stone (1982b) that predicts age, number of vertical layers, and species composition of tree aggregations in a giant sequoia-mixed conifer forest; and a gap model of succession in mixed conifer forest using fire (Kercher and Axelrod 1984) as cited in Agee and Huff (this proceedings). Several of these models have shortcomings (van Wagtendonk 1985). The original FYRCYL did not have a vegetation subroutine, so effects of succession and fuel accumulation were not considered, while Bonnicksen and Stone's (1982b) model did not produce fire frequencies and intensities. A revised recent FYRCYL model (van Wagtendonk 1985) combines vegetation, fuel, weather, and lightning to simulate fires that interact with vegetation and fuels and predicts effects of no fire, lightning fire, and suppression scenarios on fuel energy, basal area, and density by species.

Another approach is the empirical/field method emphasizing observations and measurements of real forest fires. Fire research in Canada has tended to follow this method (Van Wagner 1984). Theory was not ignored; physics and math complemented essential field observations but never supplanted them. The drawbacks of this strategy are that independent variables are less controllable and the results of a particular study are less widely applicable. Yet the combustion process and its impacts were felt to be so complex that modeling forest fires in the laboratory would be less productive than letting the forest be the empirical integrator of all fire effects, short-term and long-term.

Fire History Methodology.— Looking specifically at research methods used in fire history, two of the important early publications describing use of tree-ring technology for determining fire history were those by Clements (1910) working with lodgepole pine in Colorado and Weaver (1951) working with ponderosa pine in many areas of the West. The recent increased need for information about past fire history in general (and fire frequency specifically) to support wilderness fire management programs has given a tremendous push to development of more sophisticated and practical techniques in fire history research.

Some of the approaches now in use to determine fire frequency, fire intensity, and fire size in various wilderness ecosystems (Alexander 1980) include:

1. Use of both modern fire records and presettlement written records such as early diaries and maps by Jesuit priests or explorers and reports of early government agency personnel.
2. Use of oral records of Indian fires (Lewis 1977, 1980, 1985; Barrett 1980, 1981).
3. Use of aerial photographs and satellite imagery to map fire patterns or mosaics (Heinselman 1973; Tande 1979; Alexander 1980; Hawkes 1980).
4. Retaking early photographs from the same photo site to illustrate vegetative changes in the absence of fire (Progulske 1974; Gruell 1980, 1983; Houston 1982).
5. Development of stand origin and fire history maps from forest inventory maps plus stand age data.
6. Use of dendroclimatological techniques to determine relationships of past climate to fire history (Alexander 1978, 1980).
7. Use of paleoclimatic reconstruction techniques involving charcoal stratigraphy and charcoal-pollen analyses (Terasmae 1967; Swain 1973; Weeks 1976; Cwynar 1977; Mehringer and others 1977; Hemphill 1983; Smith 1983).
8. Computer modeling of stand-age class distribution projections over time (Suffling and others 1980). Both van Wagtendonk (1972) and Agee and Flewelling (1983) used climatic data with spread data to simulate fire frequency, rather than relying on age class or fire scar data.
9. Use of tree-ring increment cores from fire-initiated stands and fire scar data from cross-sections or wedges from either dead or living trees to determine intervals between fires and some indications of areal extent of fires and fire intensities.

The most common method of determining fire history in forests is by dating fire scars using techniques similar to those developed in dendrochronology; this is supplemented by increment core records from stands that originated after high-intensity fires. The standard form of this technique (Arno and Sneck 1977) has five main steps (McBride 1983). These steps and their strengths and weaknesses are:

1. Selection of samples: It is essential that they be stratified into units expected to have similar fire occurrence and behavior (Kilgore and Taylor 1979; McBride 1983) for grouped data to be meaningful.
2. Removal of samples from trees: Techniques range from complete cross-sections, wedges, and thin wafers (Heinselman 1973; McBride and Laven 1976; Arno and Sneck 1977; Dieterich 1980b) to increment cores (least accurate, but also least impact on wilderness resources) (Heinselman 1978 in Alexander 1980; Means 1985).
3. Dating fire scars: Major problems here involve (a) recognizing fire scars and separating them from wounds caused by frost crack, root rot, insects, or other sources (Row and others 1974; McBride 1983; Stuart and others 1983), and (b) missing, discontinuous, or false rings. The latter problems can be solved by crossdating (Madany and others 1982), matching a ring pattern of wide and narrow rings from one specimen to another, or

through use of recent, more sophisticated techniques involving x-ray density measurements and computer processing of data (Parker 1972). Achieving greater accuracy through crossdating, however, is time consuming and expensive, and not always necessary.

4. Summarizing fire data: Individual fire dates are then combined to produce master fire chronologies for a sizable area or composite fire intervals for a smaller area (Arno and Sneck 1977; Kilgore and Taylor 1979; Dieterich 1980; Arno and Peterson 1983).

5. Calculation of mean fire-free intervals: Such intervals can be calculated for different size areas, different aspects or elevations, different habitat types, different historical time periods, and different sizes and intensities of fires (Kilgore and Taylor 1979; McBride 1983). The size of area being considered is extremely important in determining intervals between fires. This can be calculated for the individual tree, a small group of trees, a large stand (200-800 acres), or an entire watershed or forest region (Kilgore and Taylor 1979; McBride 1983; Arno and Peterson 1983; Dieterich and Swetnam 1984). In general, the larger the unit size, the greater the number of fires and the shorter the interval between them without any basic change in ecosystem function (Kilgore 1981). Arno and Peterson (1983) suggested that smaller sized units may be best in areas where trees are long-lived and readily fire scarred, while larger units may be required to piece together fire history in areas where the oldest surviving trees are scattered or very resistant to scarring.

Fire Effects Methodology.—A number of study designs and techniques have been used to measure the broad spectrum of variables involved in the effects of various intensities of fire on different vegetative types and ecosystems. A fairly standard experimental design for obtaining such fire effects data from prescribed burning (see Kilgore 1971a,b, 1973a; Agee 1973; van Wagtendonk 1974) is outlined by these six steps:

1. Develop testable hypotheses from a specific problem statement.
2. Decide on applicable methods after setting up an appropriate experimental design.
3. Establish several experimental burn plots or transects and control plots or transects; measure appropriate vegetative, fuels, soil, water, air, or wildlife variables prior to the burn.
4. Burn the sites under known weather and fire behavior parameters.
5. Make postburn measurements of the same variables on both burn and control plots.
6. Analyze the changes in variables due to impact of the given intensity of prescribed fire under known weather conditions.

Depending on the objectives, such before, during, and after studies of fire impacts can be directed toward gathering data and analyzing effects by particular species; ecosystems or vegetation types; particular well-known fires; specific variables of interest, such as fuels or wildlife; geographic region; or long-term effects (more than 10 years). Examples of these six approaches are:

1. Fire impacts by species, such as ponderosa pine (Cooper 1960), giant sequoia (Hartesveldt 1964; Harvey and others 1980), redwood (*Sequoia sempervirens*) (Veirs 1982), lodgepole pine (Taylor 1969).
2. Fire effects by ecosystems or vegetation types, such as California red fir (*Abies magnifica*) forests (Kilgore 1971b), sequoia-mixed conifer forest (Kilgore 1973a), ponderosa pine/western larch (*Larix occidentalis*)/Douglas-fir (*Pseudotsuga menziesii*) (Lunan and Habeck 1973).
3. Fire effects by particular wildfire, such as three historical fires in Olympic National Park, WA (Agee and Smith 1984); the Independence Fire of 1979, Selway-Bitterroot Wilderness, ID, the largest natural fire to burn to date under wilderness fire programs (Keown 1980, 1985a); the Little Sioux Fire of 1971, Boundary Waters Canoe Area, MN (Books and others 1971).
4. Fire effects by impacts on specific variables, such as: (a) fuels (Pickford and others 1977; Agee and others 1978); (b) crown scorch (Van Wagner 1973); (c) crown-fire potential (Kilgore and Sando 1975); (d) seedling germination (Kilgore and Biswell 1971); (e) hydrologic properties or water quality (Agee 1973); (f) wildlife, generally, or specific species or groups of species such as birds (Kilgore 1971a; Koehler and Hornocker 1977); and (g) insects or disease (Gara and others 1985).
5. Fire effects by geographic region or wilderness, such as Selway-Bitterroot Wilderness, ID (Habeck 1976); Sequoia National Park, CA (Vankat 1970); Boundary Waters Canoe Area, MN (Heinselman 1973).
6. Long-term fire effects, such as Lyon's (1976, 1984) 21 years of postfire change or chronosequence approaches carefully substituting space for time (Taylor 1969; Huff 1984).

While the study designs noted above have in some cases been developed with wilderness fire research needs in mind, the particular techniques used to measure individual variables are almost always standard methods utilized in all studies of vegetation, soil, water, and wildlife work and, hence, will not be discussed specifically. Descriptions of such standard techniques can be found as follows:

Fuel quantity methods	Brown and others 1982
Fuel moisture methods	Norum and Fischer 1980 Sackett 1980
Weather measurements	Fischer and Hardy 1976
Fire variables	Rothermel and Deeming 1980
Vegetation sampling methods	Brown and others 1982 Britten and Clark 1981 van Wagtendonk and others 1982
Smoke and air quality methods	Mobley and others 1976
Water quality methods	Ponce 1980
Soil exposure methods	Gleason 1957 Beaufait and others 1977
Wildlife populations and habitat measurements	Nudds 1977 Giles 1969 Kendeigh 1944

Fire Behavior Methodology.—Measuring fire behavior is extremely important for meaningful interpretation of

fire effects information (Van Wagner and Methven 1978; Methven 1978). Most monitoring efforts on wilderness fires are aimed at obtaining information on fire behavior and weather to assure managers that a given prescribed fire is behaving as predicted or to allow prediction of movement of a wildfire during the next few hours or days, in terms of human safety and impact on property. Variables usually measured are flame length and rate of spread; techniques for making these measurements are covered by Rothermel and Rinehart (1983). From these measurements, fire line intensity and heat per unit area can be calculated (Rothermel and Deeming 1980). Techniques for predicting and estimating rate of spread, flame length, and fire line intensity include nomographs (Albini 1976), the hand-held calculator (Burgan 1979), and computer systems such as BEHAVE (Burgan and Rothermel 1984; Andrews 1986). These techniques are compiled in a manual for field use by Rothermel (1983).

Fire behavior predictions are useful in wilderness fire programs for projecting fire size, perimeter length, and area growth (Keown 1985b), including how large a fire may become. Where size has been used by managers as a prescription criterion, as in Gila Wilderness fire plans (Kilgore 1982), this is a highly important estimate. The present techniques for predicting spotting distance (Albini 1979) and the current effort to predict crown fire potential (Fahnestock 1970; Rothermel 1983; Keown 1985b) offer possible assistance to wilderness fire managers in judging the likelihood of major changes in overall fire activity, including consideration of threat to human life, property, and nonwilderness lands.

Few studies of fire behavior in wilderness have quantified flame length and spread rate and correlated them with fire effects data. In a recent study in Yosemite National Park, CA, behavior predictions and observations were made for more than 230 plots that were burned with prescribed fires in six fuel types, ranging from ponderosa pine through mixed conifer and true fir (*Abies* spp.) to montane chaparral (van Wagtendonk and Botti 1984). Both the National Fire-Danger Rating System (NFDRS) and the Fire Behavior Prediction System (FBPS) tended to overpredict rates of spread and flame lengths for many plots, but underpredictions were common in the mixed conifer and montane chaparral types. "Until custom-built fuel models become available, the NFDRS and FBPS will remain the best predictors of fire behavior" (van Wagtendonk and Botti 1984).

Wilderness Fire Methodology.—Few studies are unique to wilderness or park environments, and hence relatively little has been developed to date that can be thought of as unique methodology for wilderness fire. The types of studies coming closest to this would be those addressing four issues:

1. What is "natural?"

2. How much fuel has accumulated because of fire suppression?

3. What changes in forest structure have resulted from fire suppression (both changes within stands and changes in the mosaic of vegetation communities)?

4. What have been the impacts of allowing natural fires to burn?

These issues are strongly intertwined, and I will not attempt to address them separately. Any special methods or techniques developed to address these issues might be thought of as wilderness fire methods.

Several studies have been carried out recently in Sequoia-Kings Canyon National Parks, CA, to measure unnatural fuel accumulation because of suppression of fire (Parsons 1978; Parsons and DeBenedetti 1979). Traditional fuel measurement techniques were used in these studies, although special interpretation was given to possible changes because of fire suppression. The authors also thoroughly analyzed any suppression-related changes in species composition, age structure, and densities of different size classes of each species.

Sophisticated methods involving several point-pattern analysis techniques have been employed recently by Bonnicksen and Stone (1981, 1982b). These techniques were used to characterize both the present and the presettlement horizontal structure of giant sequoia-mixed conifer forests as mosaics of homogeneous vegetative units called aggregations. These mosaics of aggregations change with respect to each other in both space and time as trees within them grow older and are replaced by younger trees. The proportion of the forest represented by any one age class or species mix, however, will remain about the same (Bonnicksen and Stone 1982b). The absence of fire in this frequent, low-intensity fire regime for the past 50 to 100 years has apparently allowed an abnormal number of aggregations dominated by younger age class true fir to become pole-sized or mature fir.

A method being used to determine effects of allowing natural fires to burn involves establishing plots on several previous fires of known ages. Such chronosequence approaches carefully substitute space for time. Researchers then analyze regrowth of tree and shrub vegetation over time with respect to apparent fire intensity and severity, climatic factors, and vegetative potential (Taylor 1969; Agee and Smith 1984).

RESEARCH RESULTS: RELATIVELY WELL-SUPPORTED KNOWLEDGE

Wilderness fire research is summarized with results from segments of general fire research on fire history, fire behavior, and fire effects. We know a fair amount about the role of fire in various ecosystems, after 70 years of research on particular regions, ecosystems, or species.

While many of these studies were not undertaken in wilderness or parks, the results will be valid for such areas, provided there were no major man-caused modifications of the vegetation or ecosystem being studied. Recent work carried out directly in park and wilderness units can be used to cross-check results from earlier studies in relatively unmodified but nonwilderness vegetative communities.

The concept of fire regimes is a useful framework around which to organize existing fire research knowledge. I will use the following fire regimes for this purpose:

1. Frequent, low-intensity surface fires (1- to 25-year return intervals).

2. Infrequent, low-intensity surface fires (more than 25-year return intervals).

3. Infrequent, high-intensity surface fires (more than 25-year return intervals).

4. Short-return-interval, stand-replacement fires (25- to 100-year return intervals).

5. Variable regime: frequent, low-intensity surface fires and long-return-interval, stand-replacement fires (100- to 300-year return intervals).

6. Very long-return-interval, stand-replacement fires (more than 300-year return intervals).

Certain fire regimes and vegetation types will be covered more thoroughly than others for two reasons: (1) more knowledge is available for some vegetation types; and (2) we need to know more about certain vegetation types and fire regimes. In certain short-return-interval fire regimes, a relatively few years' modification of the natural fire cycle can result in an unnatural ecosystem state. By contrast, a few years' alteration of the fire cycle in 300- to 400-year-return-interval fire regimes would cause relatively minor changes in similar aspects of that ecosystem.

Careful splitting of different physiographic or geographical segments of vegetation types (such as lodgepole pine) under several fire regimes is practical in table 1, but presentation of these finer differences is not practical or helpful in the general text discussion. Hence, I will include species under their most typical fire regime.

Frequent, Low-Intensity Surface Fires

We have more information on fire history, effects, and behavior in this fire regime than any of the others. During presettlement times, frequent, low-intensity surface fires were characteristic of both seral and climax ponderosa pine forests and giant sequoia-mixed conifer forests (Weaver 1951; Cooper 1960; Biswell 1967; Kilgore and Taylor 1979; Kilgore 1981). Certain Douglas-fir and western larch forests in the Rocky Mountains were kept open for centuries by frequent natural burning (Arno 1980) along with insect epidemics and other mortality factors.

The broad principle involved in this fire regime is that fire burns regularly and frequently (every 1 to 25 years) and as such rarely allows the accumulation of organic fuels to a point that higher intensity fires will develop. Few specific studies of fire behavior have been carried out in this regime. Van Wagtendonk (1972, 1974) studied spring surface fires in Yosemite National Park's ponderosa pine and incense-cedar (*Libocedrus decurrens*) forest type. Intensity increased as fuel moisture decreased from 19 to 10 percent, but the maximum intensity measured was 75 Btu per second per foot (61 kcal/s/m). In more recent work in a wider range of fuel types, van Wagtendonk and Botti (1984) found flame lengths of about 1 foot and mean rates of spread between 1 and 2 feet per minute. Such behavior appears to be typical of this fire regime.

Ponderosa Pine Forest.—Fire frequencies in presettlement ponderosa pine forest varied from 2 to 18 years in different parts of its range, with 5 to 12 years being typical (table 1). Fires were probably somewhat more frequent in some climax pine forests than seral stands. Little data are available on fire sizes. In the Gila Wilderness of New Mexico, Swetnam and Dieterich (1985) found 3,000 acres to be a conservative estimate of fire size, although they also found smaller fires recorded on only a few trees.

Mixed Conifer Forest.—In mixed conifer forests where such species as white fir (*Abies concolor*), Douglas-fir, giant sequoia, sugar pine (*Pinus lambertiana*), incense-cedar, and similar species are mixed with ponderosa pine, intervals between fires generally become longer, ranging from 9 to 42 years (table 1). Sizes of fires vary from small fires at frequent intervals to less frequent larger fires (Dieterich 1983). In a sequoia-mixed conifer forest in California, large fires (more than 2,000 acres) burned approximately every 26 years between 1782 and 1858, while moderate-sized fires (40 to 2,000 acres) burned about every 10 years and small fires were even more frequent (Kilgore and Taylor 1979).

Fire's Effects in This Regime.—The impact of fire on plant community composition in the frequent, low-intensity fire regime begins with a role in triggering release of seeds of such serotinous species as giant sequoia (Kilgore and Biswell 1971) and in preparing a seedbed, usually of mineral soil and ash, that is conducive to effective germination and survival of giant sequoia, Douglas-fir, and many species of pine (Hartesveldt and Harvey 1967). Fire also controls species composition by favoring species requiring sunlight such as pines and sequoia over shade-tolerant forms such as white fir and incense-cedar, and fire-resistant and fire-dependent species and associations over nonfire-dependent forms.

Recycling understory vegetation without damaging the overstory canopy greatly is not as dramatic a role as that found in stand-replacement type fire regimes, but it is nonetheless important. In on-site fire history studies in Sequoia-Kings Canyon National Parks, Kilgore and Taylor (1979) found no evidence of intense fires that moved from crown to crown of giant sequoia in the past 400 to 2,000 years. However, small patches of intense surface burning during a prescribed understory burning program resulted in small openings and ideal seedbed conditions for sequoia seedling germination and survival (Kilgore and Biswell 1971). Such conditions probably occurred at various times in the past, due to climatic fluctuations and localized fuel accumulations.

Most forests are made up of a small scale patchwork or mosaic of age classes, successional stages, and vegetation types brought about in part by the different way fires burn in each plant community or fire regime. In ponderosa pine forests of Arizona, for example, Cooper (1961) identified several patterns ranging from (1) a large-scale pattern of differences in density, growth, and species composition induced by local variations in topography and soils, through (2) a patchy mosaic pattern of even-aged groups averaging about 0.2 acre (0.1 ha) in size and maintained largely by fire, to (3) variations in

Table 1.—Summary of fire regimes and fire histories for selected wilderness ecosystems

Fire regime, ecosystem type	Site	Park or wilderness unit involved	Fire frequency (years)	Typical fire size[1]	Source
Frequent, low-intensity surface fires (1-25 year return interval)					
Ponderosa pine forest	Northern Arizona		2-5		Dieterich 1980a
Ponderosa pine forest	Arizona-New Mexico	Gila Wilderness, NM	4-12	Large	Weaver 1951[2]; Swetnam and Dieterich 1985
Ponderosa pine forest	California		8-10	Large (some small)	Show and Kotok 1924; Wagener 1961; McBride and Laven 1976
Ponderosa pine forest	Oregon-Washington		8-18	Large (some small)	Keen 1940; Weaver 1955, 1959; Hall 1976
Ponderosa pine forest	Montana		6-12	Medium	Arno 1980
Ponderosa pine forest	Oregon		14-30	Large	Soeriaatmadja 1966
Mixed conifer forest	Arizona		11	Small	Dieterich 1983
Mixed conifer forest	Arizona		22	Large	Dieterich 1983
Mixed conifer forest	Oregon	Crater Lake NP	9-42		McNeil and Zobel 1980
Sequoia-mixed conifer	California	Sequoia-Kings Canyon NP	9-16	Medium	Kilgore and Taylor 1979
Infrequent, low-intensity surface fires (More than 25 year return interval)					
Lodgepole pine - lower subalpine	Montana		25	Large	Arno 1976
Lodgepole pine - upper subalpine subalpine fir (*Abies lasiocarpa*)	Montana		35	Medium	Arno 1976
Lodgepole pine	Alberta, Canada	Jasper NP	27	Medium	Tande 1979
Lodgepole pine	Montana	Bob Marshall Wilderness	20-40	Medium	Gabriel 1976
Lodgepole pine—red fir	California	Kings Canyon NP	?	Small	Kilgore 1971b
Infrequent, high-intensity surface fires					
Redwood forest - southern unit	Marin County, CA	Muir Woods NM	22-27	Medium to large	Jacobs, Cole, and McBride, in press
Redwood forest - northern unit ● Mesic, near coastal sites	Humboldt County, CA	Redwood NP	250-500	?	Veirs 1982
● Intermediate sites	Humboldt County, CA	Redwood NP	100-200	?	Veirs 1982
● Xeric interior sites	Humboldt County, CA	Redwood NP	50	?	Veirs 1982

Short return interval, stand-replacement fires (25-100 year interval)					
Chaparral	S. California		20-40	Large	Byrne 1978
	S. California		30 +	Very Large	Green in Wright and Bailey 1982
Chaparral, high elevation, north slopes	S. California		50-100	Large	Vogl and Schorr 1972 in Wright and Bailey 1982
Quaking aspen (*Populus tremuloides*)	Colorado Rockies		50-100	Large	Estimated by Hendrickson 1972
Sagebrush-grass	Wyoming	Yellowstone NP	32-70	Large	Houston 1973
Spruce-fir-lodgepole pine higher elevations	Alberta, Canada	Jasper NP	74	Medium	Tande 1979
Lodgepole pine, midelevation	Wyoming	Grand Teton NP	75?	Large	Loope and Gruell 1973
Lodgepole pine	Colorado Rockies		100?	Large?	Clements 1910 in Heinselman 1981
Boreal forest: closed spruce-birch or black spruce	Interior Alaska-NW Yukon		100	Very large	Viereck 1973; Barney 1971 in Heinselman 1981
Lodgeople pine	NE British Columbia		49	Large	Smith 1979 in Heinselman 1981
Jack pine - black spruce	Minnesota	Boundary Waters Canoe Area	50	Very large	Heinselman 1973, revised in Heinselman 1981
Aspen-birch-fir	Minnesota	Boundary Waters Canoe Area	80	Very large	Heinselman 1973, revised in Heinselman 1981
Long return interval, stand-replacement fires (100-300 year intervals)					
Lodgepole pine forest - midelevations	Montana	Bob Marshall Wilderness	150	Large	Gabriel 1976
Douglas-fir forests	Pacific Northwest,		200-300	Large	Schmidt 1960
	Western Washington		50-400	Large	Martin and others 1976
			230		Fahnestock and Agee 1983
Boreal forests: spruce	NE British Columbia		103	Large	Smith 1979 in Heinselman 1981
Red-white pines	Minnesota	Boundary Waters Canoe Area	180	Medium	Heinselman 1973, revised in Heinselman 1981
Red-white pines	Minnesota	Itasca State Park	150	Large	Frissell 1973
Very long return interval, stand-replacement fires (More than 300 year interval)					
Lodgepole pine forest	Wyoming	Yellowstone NP	300-400	Large	Romme 1980
Spruce-fir forest	Montana	Bob Marshall Wilderness	300 +	Medium	Gabriel 1976 in Heinselman 1981
Cedar-hemlock forest	Washington	Olympic Peninsula	150 +	?	Martin and others 1976
			500 +		Lotan and others 1981
True fir forests	Montana		150 +	?	Antos 1977
			800		Fahnestock and Agee 1983
Western hemlock	W. Washington		600	?	Fahnestock and Agee 1983
Cedar-spruce	W. Washington		2000	?	Fahnestock and Agee 1983

[1]Fire size classes are: small = 100 acres or less; medium = 101 to 1,000 acres; large = 1,001 to 10,000 acres; very large = more than 10,000 acres (Heinselman 1981).

[2]Early studies by Weaver utilized data from single stumps, without taking advantage of the more complete fire frequency record found on a group of several trees ("cluster" in Kilgore and Taylor 1979 and composite fire interval in Dieterich 1980b). Thus data tend to be conservative minimums.

stand density within a single even-aged group, primarily due to chance factors in early stand development. Weaver (1967) noted that "Periodic burning causes development of uneven-aged stands, comprised of even-aged groups of trees of various age classes." This has been documented for mixed conifer forests by Bonnicksen and Stone (1981).

Periodic fire plays an important role in regulating dead fuel accumulations. Fire can decrease dead fuels by consuming them or increase them by killing live vegetation. While vegetative biomass accumulates with time, Brown (1985) notes this is not necessarily true for dead fuels because not all biomass is available fuel. Only that portion available to be burned is fuel and this does not include, for example, boles of living trees. Dead branches and boles of trees fall to the ground and become fuel in response to such mortality factors as fire, insects and disease, and wind and snow damage. But as Brown (1985) indicates, these factors occur in an irregular manner not necessarily related to stand age.

In a frequent, low-intensity surface-fire regime, periodic fire plays an important role in maintaining fuels at a minimal level, because natural decay rates are very slow. Biswell and others (1966) found 2 to 3 tons per acre of litter produced yearly directly beneath individual ponderosa pine, sugar pine, and giant sequoia trees. Agee and others (1978) found 1.5 to 2 tons per acre with more random sampling techniques. Such an annual increment of dead fuels may be increased by blowdowns, insects and disease, and wildfire. Under presettlement conditions, after a minimum fuel buildup (usually from 2 to 16 years) fire periodically consumed the accumulation of surface organic materials. The timing of such burns depended on the simultaneous occurrence of an ignition source and suitable weather conditions (van Wagtendonk 1972). Parsons (1978) reported that within 7 years after prescribed burning in a giant sequoia forest, fuels less than 3 inches in diameter had nearly returned to preburn levels and would again support a fire. Larger fuels and duff were still less than half the quantities that had accumulated during more than 60 years of fire exclusion.

Both horizontal and vertical continuities of fuels are also extremely important and are impacted by presence or absence of fires. Regular periodic surface fires in this fire regime have played a role in making gaps in vertical fuel continuity that prevent fires moving from ground to crown. Van Wagner (1977) has summarized some theoretical and empirical conditions necessary for the start and spread of crown fire in regimes characterized by crown fires. Studies by Kilgore and Sando (1975) of vertical live fuel loading in a giant sequoia-mixed conifer forest showed that a relatively low-intensity prescribed fire reduced live crown fuels in the lower canopy by more than half, and the mean height of the crown base was increased from 3 to 16 feet. At the same time, surface fuels 1 year after the fire were reduced sufficiently that forward rate of spread predicted by Rothermel's (1972) fire spread model dropped from 7.5 feet per minute to essentially zero. Thus, removing fuel from the intermediate layer between surface and crown fuels greatly reduced the potential for high intensity surface fires that could lead to crown fires. Chandler and others (1983) noted that "Gaps in vertical continuity of about 1½ flame heights will virtually preclude the fire from burning into the overhead stratum."

Infrequent, Low-Intensity Surface Fires

By definition, fire in this regime burns at more than 25-year intervals but with relatively low intensity. The California red fir and lodgepole pine forests of the subalpine zones of the Sierra Nevada and certain upper subalpine forests of the Rocky Mountains are included in this fire regime. Table 1 shows that fire frequencies in presettlement forests varied from 27 to at least 40 years or more, with detailed information lacking for a number of vegetation communities.

California Mixed Subalpine Forest.—In subalpine forests of whitebark pine (*Pinus albicaulis*), California red fir, and lodgepole pine in the Sierra Nevada, fires often spread slowly or not at all, and they rarely burn the crowns and kill stands of overstory trees (Kilgore and Briggs 1972). Such high-elevation areas have many natural firebreaks such as sparsely vegetated ridges, barren rocky areas, and streams and draws with relatively fire-resistant riparian vegetation. No actual fire histories have been carried out here, but fires of less than one-fourth acre account for more than 75 percent of the fires burning in Sequoia-Kings Canyon (Parsons 1981) and Yosemite National Parks (van Wagtendonk 1978). On the other hand, four fires in these parks from 1968 to 1978 burned more than 2,500 acres and one reached 10,000 acres in size with low-intensity burning over several months. In measurements made on the 4,000-acre Starr King Fire in Yosemite, van Wagtendonk (1978) found rates of spread that varied from 1 inch to 120 feet per hour, with 200 acres being the greatest area covered in 1 day. Intensities varied from 0.29 to 680 Btu/s/foot, and van Wagtendonk characterized the burn as having intensely burned patches separated by lightly burned or unburned areas.

Rocky Mountain Subalpine Forest.—Whereas high-intensity fires have clearly been a major part of the spectrum of fires found in lower subalpine forests of the Rocky Mountains, Arno (1976) concluded that fires are less frequent and intense in the upper subalpine forest because of moist, sparse fuels. In subalpine fir (*Abies lasiocarpa*) forests, fires occurred in a random pattern, with scars on adjacent trees often from different years (Gabriel 1976); this apparently resulted from a high incidence of lightning fires with a low volume of fuel and open stands.

Fire's Effects in This Regime.—The effects of fire on vegetation were related to variations both in species and in burning intensity. While brushfields were almost entirely consumed in one study area, less than 3 percent of the mature California red fir and Jeffrey pine (*Pinus jeffreyi*) were killed (van Wagtendonk 1978). Fire usually had only moderate impact on Jeffrey pine, but California red fir and lodgepole pine either burned intensely or not at all. In earlier studies, fire reduced litter, duff, and humus by about 50 percent. Few older California red fir were affected, but many fir saplings and seedlings were killed resulting in decreased coverage of fir thickets and minor adjustments in successional patterns (Kilgore

1971b). Many mature lodgepole pine were killed, while germination of pine seedlings and seedlings of nine shrubs and herbaceous species was stimulated.

In certain situations in the Rocky Mountains, fire effects similar to those found in the Sierra have been documented. In moist valley bottoms, topographically isolated drainages, and higher elevations, low- to moderate-intensity fires in western larch, Douglas-fir, lodgepole pine, and subalpine fir forests result in thinned stands, reduced fuels, rejuvenated undergrowth, and preparation of seedbeds. This brings about structural changes more than changes in species composition (Davis 1980).

Infrequent, High-Intensity Surface Fires

For most species of vegetation, this non-stand-replacement regime—by definition—holds internal inconsistencies. To be infrequent and high intensity on the one hand, yet remain a surface fire and not a stand-replacing fire on the other, requires special characteristics of the ecosystem or species involved. Although this seems to be a secondary regime for a number of lodgepole pine ecosystem types in subalpine forests of the northern United States (Heinselman 1981), the redwood is a type in which this regime is primary. The redwood has tremendously thick bark and a maximum height of more than 360 feet; as such, mature trees can withstand fairly intense surface burns without killing the trees. In addition, redwood sprouts from the base of the stem as well as along the bole after the stem or foliage is damaged or killed by fire.

Redwood Forest.—Sample fire histories from table 1 indicate a variation from 22 years to between 250 and 500 years in the typical interval between fires. The shorter end of this scale comes from drier inland sites near the southern end of the range of redwood distribution, in Marin County, CA (Jacobs and others in press), while the longer duration represents mesic coastal sites farther north (Veirs 1982). Even with a fire-free interval of 500 years, high-intensity, stand-replacing fires seem to be rare for redwoods. Earlier work by Fritz (1932) showed 45 severe fires over an 1,100-year period in the more northerly area, or about four fires each century on his 30-acre study site.

There are few published observations of fire behavior in redwood forests, but evidence from an 1880 fire would indicate a low-intensity fire (Veirs 1980). In a 1974 fire, spread rates were 2 to 3 feet/minute downhill and only slightly faster uphill, with less than 2-foot flame lengths. In spite of an extremely dry summer, low wind conditions and a slight inversion resulted in a low-intensity fire. Fritz (1932) described much more intense burning following an unprecedented drought in 1929 when fires "burned fiercely" for several weeks and covered more than 10,000 acres.

Fire's Effects in This Regime.—Stone and others (1972) believed that redwoods are seral and strongly dependent on fire and flooding for their perpetuation. Franklin and Dyrness (1973) concurred in this, based on massive fire scars on almost all large redwoods in one area. Others feel the species is climax because of its high shade tolerance (Waring, personal communication, in Franklin and Dyrness 1973). Fairly complex and species-specific responses to fire are involved in the redwood ecosystem. Much of this is still being worked out by various researchers (Veirs 1980, 1982; Jacobs and others in press). Fire effects vary considerably from the drier inland sites to the more mesic coastal sites in this fire regime. In the moist coastal area, for example, Douglas-fir apparently only becomes established following those rare occasions when high-intensity fires make some openings in overstory canopy (Veirs 1982). Other climax species, such as redwood, tanoak (*Lithocarpus densiflorus*), and western hemlock (*Tsuga heterophylla*) do well with or without low-intensity fires.

Short-Return-Interval, Stand-Replacement Fires

This short-return-interval, high-intensity fire regime is characteristic of several shrub vegetation types as well as parts of the lodgepole pine and boreal and near-boreal forests of North America. But the long-return-interval fire regime is more typical for both the boreal forest and lodgepole pine, and such species will, therefore, be described in that section. Chaparral, sagebrush-grass, and quaking aspen (*Populus tremuloides*) have aboveground vegetation that is killed by periodic, intense burning—either crown fires or high-intensity surface fires—but each survives by sprouting from root crowns or by reseeding.

Chaparral.—This is perhaps the most flammable vegetation type in the United States and has its counterparts in many mediterranean-climate ecosystems around the world. It exhibits some of the most high-intensity fire behavior found anywhere. Inherent chemical, physical, and physiological properties of the vegetation contribute to its adaptation to fire and drought in a way that leads to an increased probability of high-intensity, fast-spreading, large fires occurring as the vegetation grows older (Philpot 1977). With high temperatures, low humidities, and high Santa Ana (foehn) winds typical of wildfire conditions in this type, flame lengths of more than 100 feet and spread rates of at least 500 feet per minute have been observed. The recurrence interval for large fires in California chaparral is 20 to 40 years (Byrne and others 1978) with large, severe fires tending to occur in brushfields older than 30 years (Green in Wright and Bailey 1982). At elevations above 4,000 feet on northern aspects, however, fire intervals may be from 50 to 100 years.

Sagebrush-Grass.—This vegetation covers at least 96 million acres in the Western United States, mostly below the pinyon-juniper zone (Wright and Bailey 1982). In presettlement times, maximum fire intervals in this community in northern Yellowstone National Park, WY, were every 32 to 70 years (Houston 1973). Fire behavior can vary from minimal burning conditions with flame lengths of 1 to 3 feet and fires that barely spread to 15- to 20-foot flame lengths and spread rates of more than 150 feet per minute.

Quaking Aspen.— In contrast to the previous two shrub types, aspen has been described as an "asbestos forest" in some areas because it does not burn readily even when surrounding coniferous forests will burn. Relative

humidities below 35 percent, surface duff moisture less than 20 percent, and 4- to 15-mi/h winds are said to be required for successful burning (Wright and Bailey 1982); this can only take place during the occasional brief stretch of dry weather conditions between snowmelt and leaf flush in the spring or after leaf fall in the autumn. Flame lengths of 3 feet have been observed in living aspen and up to 30 feet in dead aspen stands (Wright and Bailey 1982). Studies are currently underway to resolve some of the difficulties in prescribed burning in western aspen forests and to increase our knowledge of fire effects in aspen (Brown and DeByle 1982). Fire frequencies of 50 to 100 years have been hypothesized by Hendricksen (1972) for aspen in the Colorado Rockies. This is supported by observations that, while aspen may live to 200 years in the absence of intense fire, stands tend to deteriorate after 80 to 100 years and be replaced by conifers (Loope 1971).

Fire's Effects in This Regime.—The dramatic impact of the interplay between fire frequency and intensity on the one hand and vegetation structure and reproductive strategies on the other is illustrated by recent work in southern California chaparral. Keeley and Zedler (1978) noted that chaparral is adapted to both short and long fire-free intervals, reflecting how unpredictable fire is in that environment. They suggest a model in which a short cycle (25 years) favors sprouting shrubs over those reproducing entirely from seed and a long fire cycle in which "sprouters" and "seeders" coexist. In the short cycle, there are fewer dead shrubs before the fire, more potential resprouts, less intense fires, lower fire-caused mortality of sprouting shrubs, and smaller openings for seedlings. In the long cycle (100 years), however, there are more dead shrubs before the fire, fewer potential resprouts, higher intensity fires, more fire-caused mortality of sprouting shrubs, and larger openings for seedlings. In the case of aspen, the species tends to be fairly short-lived, is susceptible to many diseases, and cannot survive or reproduce in the shade of competing conifers such as Douglas-fir (Loope 1971; Gruell and Loope 1974). Without regular fire, aspen does poorly, and recent fire suppression is thought to be a major factor in aspen decline.

Variable Regime: Frequent, Low-Intensity Surface Fires and Long-Return-Interval, Stand-Replacement Fires

Long-return-interval crown fires were part of the natural fire regime for many forest ecosystems in four major regions of North America: (1) the boreal forest of northern Canada and interior Alaska; (2) the Great Lakes forests; (3) the forests of the Pacific Northwest; and (4) most of the Rocky Mountain wilderness forests (Heinselman 1978, 1981; Franklin and Hemstrom 1981). In some areas, however, the regime varied between relatively frequent, low- to moderate-intensity surface fires and long-return-interval stand-replacement fires (including severe surface fires), depending on weather conditions and ignition factors on particular sites. When wind and other weather conditions are favorable for intense burning, the likelihood of crown fires depends on (1) the spacing of trees; (2) the quantity of crowns per unit area; (3) the amount and arrangement of surface fuels; and (4) how high the crown canopy is above the surface fuel heat source (Brown 1975). Such intense fires have occurred periodically at intervals between 100 and 300 years in lodgepole pine, western white pine (*Pinus monticola*), and western larch forests of the Rocky Mountains; in Douglas-fir and lodgepole pine forests in the Cascades (Fahnestock 1977); in black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), lodgepole pine, and aspen-birch forests of the boreal forest region as well as the Lake Superior region (Heinselman 1978, 1981, 1985). In the latter region, red and white pine sites had a regime of light to moderate surface fires at 20- to 40-year intervals combined with the long-interval crown fire regime.

Boreal Forest.—During presettlement times, the dominant fire regime in the main boreal forest regions of Canada and interior Alaska was apparently one of high-intensity short- to long-return-interval crown fires (or severe surface fires). These were large to very large in size (Heinselman 1981), often covering more than 25,000 acres and sometimes more than a million acres (Heinselman 1985). In the drier regions of northwestern Canada and interior Alaska, fire cycles probably averaged 50 to 100 years; by contrast, cycles of 100 to 300 years were found in eastern Canada, with its wetter climate, and near treeline in the open subarctic spruce-lichen woodlands. Some jack pine and lodgepole pine forests in western Canada have regimes that include medium-intensity surface fires at intervals of about 25 years that do not kill whole stands. All references to fire regimes in the boreal forest discussion above and Great Lakes forests discussion below rely largely on the extensive studies and summaries prepared by Miron Heinselman (1973, 1978, 1981, 1985).

Great Lakes Forests.—The presettlement Great Lakes forests had three distinct fire regimes: (1) jack pine and spruce-fir forests with very large stand-replacement crown fires or surface fires every 50 to 100 years in the west and 150 to 200 years in the east (such fires in Boundary Waters Canoe Area sometimes exceeded 250,000 acres in size); (2) red and white pine forests with combinations of moderate-intensity surface fires at 20- to 40-year intervals, and more intense crown fires at 150- to 300-year intervals; and (3) mixed aspen-birch-conifer forests with high-intensity surface or crown fires (while intervals are less sure here, spruce budworm outbreaks occurred every 40 to 70 years, creating tremendous fuel loads at those intervals).

Pacific Northwest Douglas-fir Forest.—The fire disturbance pattern in the Pacific Northwest generally is one of infrequent, stand-replacing crown fires that occur after intervals of several centuries (Franklin and Hemstrom 1981). While analysis of age structure and developmental history in this region is just beginning, it would appear that many Douglas-fir forests came in over a long regeneration period (more than 100 years) following one or more major fires that occurred about 500 years ago. Such major fire episodes seem to correlate with dry climatic conditions. Earlier authors felt the mere presence of Douglas-fir on a given site in the

Northwest was considered evidence of periodic timber-killing fire (Martin and others 1976) at frequencies of 50 to 400 years. The important regional characteristics noted by Franklin and Hemstrom (1981) were that in the Pacific Northwest trees grow very large and old; the forests recover slowly after a disturbance like fire, with canopy closure taking 40 years or more; and regeneration of trees after the fire may occur over a period of 100 years or more. More recent work has suggested that on drier sites more frequent fire and a patchier forest mosaic existed (Agee and Dunwiddie 1984).

Rocky Mountain Forests of Lodgepole Pine.—Fire regimes in the Rockies are extremely complex, reflecting the great variation in climate, topography, vegetation, and productivity of mountainous regions (Heinselman 1985). One aspect of the vegetative complexity is the wide ecological amplitude of lodgepole pine. Lodgepole is an extremely adaptable species; it seems to be a fire, edaphic, or topoedaphic climax species that occupies sites that are too dry, too wet, too cold, too infertile, or in some other way unsuited to other species (Wright and Bailey 1982). In some areas it occurs in even-aged stands resulting from periodic stand-replacing fires, while on other sites it occurs with multiple ages, sizes, densities, and height classes, interspersed with small even-aged stands. The two dominant regimes in most presettlement wilderness forests were: (1) long-return-interval crown fires (perhaps 100 to 300 years) in the continuous forests of lodgepole pine mixed with spruce and fir, and (2) shorter return-interval (5 to 60 years) low- to moderate-intensity surface fires in the lower elevation Douglas-fir, aspen, and ponderosa pine stands, grassy parklands, and in adjacent open lodgepole pine stands (Heinselman 1978).

The major vegetation pattern found in lodgepole pine today was caused by stand-replacement fires, although many uneven-aged lodgepole pine stands result from lower intensity surface fires (Brown 1975). Most individual fires were low-intensity, creeping, surface fires, but most acreage was burned by the occasional high-intensity crown fires that occurred during severely dry and windy weather (Lotan and others 1985). Average intervals between crown fires varied from 60 to 400 years or more, although lodgepole pine has a lifespan that varies with site and geographic locations from 80 to 400 years, and the species tends to be eliminated from sites having very long intervals between fires (Antos 1977).

In Yellowstone National Park and adjacent wilderness, Despain and Sellers (1977), Romme (1980, 1982), and Romme and Knight (1981) concluded that most stands will not sustain crown fires until they develop a significant understory component of Engelmann spruce (*Picea engelmannii*) and subalpine fir 300 years or more after the previous fire. Sizes of recent such fires have been about 1,000 to 8,000 acres (Heinselman 1985). Large areas of lodgepole pine have been found by Despain (1983) with almost no spruce-fir component; he concludes these are essentially self-perpetuating climax lodgepole pine stands that often exceed 300 to 400 years of age with no evidence of fire since establishment. Similar stands occur in the Sierra Nevada (Parker in press).

Most fires in lodgepole pine are either very slow and smouldering or rapidly moving, intense crown fires (Lotan and others 1985). In large summer wildfires, both high- and low-intensity fire behavior can be triggered by diurnal weather changes; with winds down at night, the tendency to crowning behavior decreases and the fire creeps and smoulders in erratic fashion, resulting in a thinned stand with spotty exposure of mineral soil (Muraro 1971). By the following day, however, as temperatures and winds increase, surface fires increase in intensity until crowning again becomes more general, and, depending on fuels and forest structure factors noted earlier, may become very severe with not only needles, but branches up to one-half inch in diameter consumed, as well as some involvement of larger boles. Such variations have tremendous impact on fire effects. These effects range from (a) a thinned stand, or (b) a very low density stand of lodgepole pine, to (c) an extremely dense stand and a dead snag forest.

Fire's Effects in This Regime.—The intensity and frequency of fires in lodgepole pine largely determine establishment of seedlings and subsequent development of stand density, age structure, and species composition (Brown 1975; Kilgore 1981; Lotan and others 1985). Higher intensity fires tend to favor lodgepole pine over such species as Douglas-fir and western larch, depending on local winds, topography, and fuels. In certain instances, frequent fire may prevent lodgepole pine from invading aspen where the two grow in mixed stands, except where intense burns kill aspen roots (Brown 1975). The timing of the fire also makes a difference. Burns preceding a good larch seed crop tend to favor larch. It is harder to predict species composition of a mixed conifer forest involving lodgepole after a low-intensity fire.

Such mortality factors as the needle miner, bark beetle epidemics, mistletoe infestations, and death of suppressed trees in the understory of a dense forest all have impacts on species composition, successional pattern, vegetation mosaic, and fuel accumulations. These factors augment buildup of surface fuels that increase the probability of large, high-intensity surface fires (Brown 1975).

While fire effects in such a complex forest community and region are also many and complex, one conclusion consistently reached by scientists and resource managers working in the Northern Rocky Mountains is that there are few areas in which climax forests of spruce (*Picea* sp.), fir (*Abies* sp.), hemlock (*Tsuga* sp.), and western redcedar (*Thuja plicata*) have been allowed to develop. Instead, fire—whether frequent and of low intensity or less frequent and of higher intensity—has repeatedly favored the development of stands of intolerant, fire-dependent species such as lodgepole pine, aspen, western larch, western white pine, ponderosa pine, and Douglas-fir (Wellner 1970; Habeck and Mutch 1973; Weaver 1974; Arno 1980).

Very Long-Return-Interval, Stand-Replacement Fires

Stand-replacement fires at mean return intervals longer than 300 years are characteristic of ecosystems in

which shade-tolerant species are dominant; these include the spruces, true firs, western redcedar, and western hemlock. These species tend to occur on moist environments. In discussing such long-rotation types, Habeck (1985) notes they do not exhibit the same level of midsummer dryness found in short-fire-interval vegetation types and thus only occasionally burn extensively. When this does occur, the fire may remain a low-intensity burn, or it can sometimes become a high-intensity stand-replacement burn (Habeck 1976; Fahnestock 1976; Despain and Sellers 1977; Davis and others 1980), depending on climatic and fuel factors.

Spruce-Fir Forest.—These forests are so damp they seldom burn (Weaver 1974) except during extreme droughts. During those periods, fires burn very intensely through these forests because their highly flammable green limbs are close to the ground. In the Northern Rocky Mountains generally, Arno (1980) reported that moist subalpine fir-Engelmann spruce forests had fire-free intervals of 150 years or more, and that when fire did come, it was usually a high-intensity, stand-replacing fire. Intense burning in 350-year-old spruce-fir forests in Yellowstone National Park was apparently related to such forest structural factors as compact growth form, with numerous small branches close together, lower branches that did not self-prune, a fruticose lichen that had accumulated on the branches, and heavy accumulations of duff and rotten wood (Despain and Sellers 1977).

Cedar-Hemlock Forest.—Relatively little information on fire frequency or intensity is available for either of the extremely moist forests: (1) western hemlock-western redcedar of the Northern Rocky Mountains, and (2) Sitka spruce (*Picea sitchensis*)-hemlock-redcedar of the Pacific coastal forests. Hemlock-redcedar forests generally occur on sites with the dampest climate found in the Rocky Mountains, but extreme summer drought from time to time has set the stage for occasional, spectacular crown fires (Arno 1980). The most recent large conflagration was the 1967 Sundance Fire that burned 56,000 acres in northern Idaho (Anderson 1968). Earlier, high-intensity crown fires burned several million acres in 1889, 1910, 1919, 1926, and 1934, much of it in the hemlock and redcedar forests of northern Idaho (Arno 1980).

Natural fire cycles of western redcedar forests in the Selway-Bitterroot Wilderness of Idaho and Montana are from 100 to 400 years (Habeck 1985). "The oldest forest communities (over 400 years old), those burned least often, are those dominated by redcedar on the moist streamsides and in ravines" (Habeck 1976). In recent studies in northern Idaho, the mean fire-free interval for streamside western redcedar habitat types was greater than 200 years and fire intensities were low (Arno and Davis 1980). Some of the adjacent uplands in this zone (predominantly south and west exposures), however, are predisposed to spectacular crown fires at intervals of 50 to 150 years by extreme summer droughts that occur every few years, high accumulations of fuels in these productive forests, lightning, and high winds during dry periods (Arno and Davis 1980; Wright and Bailey 1982). Lotan and others (1981) hypothesized that the wettest forest in this type may burn at intervals of 500 years or longer; Fahnestock and Agee (1983) suggested a fire-return interval of more than 2,000 years for this type based on forest survey data.

True Fir Forests.—High-intensity, stand-replacement fires at intervals of about 150 years were apparently more prevalent than surface fires in grand fir (*Abies grandis*) habitat types (potential climax) of Swan Valley, MT (Antos 1977). Illustrating the extremes of true fir fire history, in the Blue Mountains of eastern Oregon, low-intensity, frequent surface fires were the rule in grand fir habitat types (Hall 1976). By contrast, a natural fire rotation averaging 434 years over the past 1,000 years was found for true fir forests of Mount Rainier National Park, WA (Hemstrom and Franklin 1982). A fire-free interval of about 500 years has also been estimated for the Pacific silver fir (*Abies amabilis*) zone, the most extensive forest zone in the Olympic Mountains of Washington (Wright and Bailey 1982).

Fire's Effects in This Regime.—In general, the shade-tolerant species represented by this fire regime are the species most susceptible to damage and mortality from fire (Lotan and others 1981); in effect, these species depend on an absence of fire. The longer a forest stand goes without fire, the more these shade-tolerant, climax species are favored over fire-dependent seral species. When fire occurs, the trend is reversed and lodgepole pine, Douglas-fir, and the spruces dominate for a period of time.

Broad Summaries of Fire Effects

Fire's Effects on Wildlife Populations and Habitats.—With the great differences in fire frequencies and intensities found in these six fire regimes and many vegetative types, it is reasonable to expect that fire would have a variety of impacts on the broad array of wildlife species found in various ecosystems (Kilgore 1976). More than 450 publications dealing with species-specific responses of birds, animals, and invertebrates to fires of varying intensities have been summarized by Lyon and others (1978), Bendell (1974), Wright and Bailey (1982), and Kramp and others (1983). Australian wildlife response to fire was summarized by Gill and others (1981), and a brief review of worldwide literature has been undertaken by Chandler and others (1983). In reviewing the results presented in more than 290 publications, mostly between 1960 and 1972, Bendell (1974) concluded that it is difficult to generalize about the effects of fire on birds and mammals. While a few researchers believe wildfire is extremely destructive of wildlife, many feel direct mortality is negligible.

Behavioral responses of birds and animals to fire appear to run the gamut from (1) wild panic for certain small rodents, such as mice, to (2) calm movement away from the fire for larger, more mobile animals like moose, caribou, swans, and raccoon, to (3) a positive movement toward the fire by many North American, African, and Australian birds and animals, including large African animals, insectivorous birds, quail, turkeys, birds of prey, and several primates (Komarek 1969; Lyon and others 1978; Chandler and others 1983). The extreme example of positive behavior response to fire may be that of the firehawk, a predatory and scavenging bird from Australia that deliberately sets fire to grass and

brushland to assist its scavenging. Lockwood (1962) reported that "I have seen a hawk pick up a smouldering stick in its claws and drop it in a fresh patch of dry grass half-a-mile away, then wait with its mates for the mad exodus of scorched and frightened rodents and reptiles. When that area was burnt out the process was repeated elsewhere."

This spectrum of behavioral responses of wildlife to fire is paralleled by a spectrum of responses to the far more important changes in wildlife habitat—food, cover, and microclimate. In a state-of-knowledge review of the effects of fire on fauna, Lyon and others (1978) concluded that: (1) While fire may temporarily displace species dependent on late stages of plant community development, such as caribou, marten, wolverine, and fisher; (2) there is a remarkable stability of species numbers and populations of smaller birds and animals following fire; and (3) in general, larger animals such as moose, deer, elk, black bear, and grouse increase in numbers after fire.

In terms of their response to fire, wildlife have been grouped into one of four categories (Kramp and others 1983):

1. Fire-intolerant species, like the hermit thrush, spotted owl, and white-footed mouse, decrease in abundance after fire.
2. Fire-impervious species, like the Steller's jay, Townsend's solitaire, and pronghorn, are unaffected by burning.
3. Fire-adapted species, like the bobwhite quail (Stoddard 1935), western wood pewee, junco, elk, coyote, and perhaps the grizzly bear (Zager and others 1980; Madel 1982; Craighead and others 1982), are associated with habitat that is characterized by recurring fires of various intensities, but they are not fire-dependent.
4. Fire-dependent species, like the Kirtland's warbler and perhaps the California condor (Wright and Bailey 1982) are associated with fire-dependent and fire-adapted plant communities, and require fire to provide some aspect of their habitat.

Considerable variation in wildlife population response to habitat changes caused by fire may be related to differences in: intensity, severity, and duration of the fire; the season of burning; the vegetation type and animal species involved; and whether we are considering short-term or longer term effects.

The influence of fire on wildlife habitat can be summarized with several broad principles (Kramp and others 1983): (1) Quantity and quality of browse for herbivores often increase immediately after fire; (2) fire increases quantity or availability of berries and seeds for birds and mammals; (3) in boreal forests, fire tends to eliminate some forage plants associated with older stands of timber, such as arboreal lichens; (4) fires may increase populations of surface and wood-boring insects that are important to quail, woodpeckers, and other insectivorous birds, but decrease populations of other pest insects and animal parasites; (5) fire impacts cover by changing the scale and pattern of vegetation mosaics as well as "edge" and diversity of related wildlife habitat through frequency, intensity, and size of burn; and (6) fire impacts succession and alters plant species composition and vegetation structure in ways that favor some wildlife species and not others.

Fire's Effects on Insects and Diseases.—A bibliographic data base of 175 publications has recently been compiled that deals with fire's effects on insects and diseases and their habitats in the Northern Rocky Mountains. A brief summary of that bibliography (Barrett 1985) concludes that relatively little quantitative research has been devoted to interactions between fire, insects, and diseases, although there has been considerable speculation about possible ecological relationships (Miller and Keen 1960; Roe and Amman 1970; Alexander and Hawksworth 1976; Parmeter 1977; Barrett 1985). Many fire ecology publications focus on vegetative succession with brief discussion of possible effects of fire or suppression of fire on habitats of insects and diseases. Insect and disease research in general has concentrated on a few economically important species on lands managed intensively for timber, including the mountain pine beetle (*Dendroctonus ponderosae*), spruce budworm (*Choristoneura occidentalis*), and dwarf mistletoe (*Arceuthobium* spp.). Little work has been done on lands managed as wilderness or parks.

Insects and diseases are important in modifying the age structure of many forests and in turn the frequency and intensity of subsequent fires (Brown 1975). Conversely, "fire or the lack of it regulates the total vegetative mosaic, and the age structure of individual forest stands within it" (Wright and Heinselman 1973) which, in turn, influence insect populations. For example, in the absence of fire in the Northern Rockies, mountain pine beetle activity leads to replacement of lodgepole pine by Douglas-fir at lower elevations and by subalpine fir and spruce at higher elevations. When extensive stands of lodgepole pine reach maturity, insect outbreaks create fuel concentrations that make large-scale fires possible. These fires, of course, result in new stands of the host tree, temporarily free from insect attack.

Presettlement fire played an important role in maintaining more open stands of ponderosa pine, larch, Douglas-fir, and true firs that were less susceptible to outbreaks of western spruce budworm. But decades of fire suppression have now allowed development of dense, multistoried stands of shade-tolerant host species preferred by the budworm (primarily the true firs and Douglas-fir). Ideal budworm habitat involves (1) shade-tolerant conifers; (2) dense, overcrowded stands, with much crown contact; (3) multistoried stands; (4) stressed trees as opposed to vigorous trees; (5) older mature stands; (6) warm, dry locations such as south-facing aspects on moderately steep slopes at lower elevations; and (7) stands with continuity of susceptible host type in adjacent or surrounding areas (Carlson and others 1985). Clearly, low-intensity, frequent fires in these regimes would have reduced many of these characteristics and in so doing would have held down habitat available for budworms. Fire exclusion, on the other hand, has directly supported development of sizable acreages of ideal habitat in such western wildernesses as the Selway-Bitterroot, Bob Marshall, Scapegoat, Anaconda-Pintler, Spanish Peaks, and Welcome Creek (Carlson and others 1985).

The relationship between fire and disease is complicated both by the variability of fire intensity and frequency and by the complexity of interactions between fire and disease. In the absence of fire, numbers of trees infected, intensity of infection, and degree of damage increase with age of trees or stands and size of trees. The rate of spread through multistoried stands is also more rapid than through single-storied stands (Parmeter 1978).

As one example, intense fires tend to have a sanitizing effect on mistletoe-infected stands, allowing young trees to develop without mistletoe raining down from above; partial burns create ideal conditions for rapid spread of mistletoe in even young stands (Alexander and Hawksworth 1976). Mistletoe, on the other hand, kills and stunts trees and causes spike tops and witches' brooms that modify vertical structure of the forest, providing "ladders" for fire to ascend and consume tree crowns. This obviously increases fire hazard, flammability, and fire intensity. Fire may encourage spread of the mistletoe parasite by conversion of nonsusceptible climax spruce-fir forests to mistletoe-susceptible nearly pure stands of lodgepole pine (Alexander and Hawksworth 1976). In some areas of the Northern Rockies, fire suppression has allowed mistletoe-infected Douglas-fir to increase in stands that were formerly dominated by uninfected ponderosa pine.

Prescribed burning on pine plantations in the South reduced pine mortality and total infection by *Heterobasidion annosum* (*Fomes annosus*) root rot (Froelich and others 1978). The impacts of fire on the fungus were greatest where the disease was most serious.

One of the first concentrated efforts at a more detailed understanding of fire-insect-disease interactions is in climax lodgepole pine stands with sparse fuels in south-central Oregon (Gara and others 1985). Initial work has led to the conclusion that mountain pine beetle epidemics create scattered downed fuels that increase likelihood of low-intensity surface fires that lead to root damage and basal fire scars. The damaged roots become infected, experience fungal decay, and in time a succession of fungal organisms (*Poria* spp.) invade and decay the bole. The mountain pine beetle, in turn, preferentially lands upon these trees and kills more scarred trees than unscarred trees. Beetle activity apparently leads to spatially clumped kill patterns and hence spatially clumped seedling establishment and mosaic patterns, in part related to aggregating behavior of beetles in response to pheromones (Stuart 1983). Past fire history has included a stand-replacement fire in 1840 and a low-intensity surface fire in 1898; such intensity differences have a strong bearing on stand structure, mosaic pattern size, and tree vigor, all of which impact susceptibility to beetle attack and fire relationships. Many other complex and interesting interactions are being investigated in what appears to be a highly productive line of study for future understanding of insect/disease/fire relationships in wilderness ecosystems.

It appears that human efforts to decrease fire frequency often lead to conditions favoring growth of forest insects or disease organisms. Such growth in turn affects forest structure and fuel buildup in a way that enhances the likelihood that the forest will burn with greater intensity than would have been the case otherwise.

Fire's Effects on Nutrient Cycles.— Mineral absorption by plants is a constant drain upon the soil (Behan 1970). A sizable quantity of minerals is incorporated in living and dead tree trunks and retained for many years, while needles and small twigs are dropped annually as litter. Minerals are gradually returned to the soil from such litter by leaching and the slow action of decomposer organisms. But, in many ecosystems, fire plays a major role in returning various mineral nutrients to the soil.

The immediate effect of fire is the conversion of organic matter to ash and charred materials (Boerner 1982), with some loss to the atmosphere by volatilization and some material remaining incompletely burned. Of those materials that are burned, any nutrients not volatilized or washed from the soil will be available for use by vegetation (Boerner 1982). While there is no quantitative model to predict transformation of elements and subsequent soil chemical changes from fire, there is general acceptance that available phosphorus, potassium, calcium, and magnesium levels increase following burning (Hare 1961; St. John and Rundel 1976; Wells and others 1979). It appears that total nitrogen decreases immediately after burning, but there tends to be an immediate increase in soluble or available nitrogen and an increase in total nitrogen over time, in part because of nitrogen fixation (St. John and Rundel 1976; Wells and others 1979). Conflicting research findings about the impact of fire on nitrogen result in part from failure to make this distinction as well as failure to note differences in fuel characteristics and fire intensities.

Overall, low-intensity surface fires facilitate cycling of nutrients and generally do not increase soil erosion, while high-intensity fires volatilize large amounts of nitrogen, disrupt soil structure, and may induce water repellency and erosion (Wells and others 1979). In natural ecosystems, rates and pathways of nutrient cycling are influenced by fire frequency and intensity. "In the absence of fire, nutrient cycles . . . can be partially or severely blocked by incomplete decomposition of biomass" (Wright and Heinselman 1973). Without natural fire, there tends to be an accumulation of fuels in many systems that leads to the likelihood of even higher intensity fires, with possible adverse consequences on soil nutrients.

Fire's Effects on Diversity and Stability.—There is considerable disagreement about how to measure these basic and fundamental concepts; it is thus difficult to compare the effects of fire on these factors in wilderness ecosystems. Vogl (1970) noted that "If stability is defined as the ability to resist change, then . . . vegetative cycles maintained and driven by fire must be considered to be stable." As such, lodgepole pine communities would be considered very stable, because fires in such seral communities result in a replacement forest of similar structure to that originally found there, while fire in a climax spruce-fir forest results in extreme changes (Brown 1975). In such vegetation where large crown fires are typical, individual patches of a mosaic may cover

thousands of acres in dynamic patterns, yet the mosaic as a whole changes little over time. "... the patches—like the pieces of a kaleidoscope—are periodically rearranged by fire and succession" (Heinselman 1978).

While earlier concepts of climax communities would have defined them as somehow inherently more diverse and stable than pioneer communities that follow fire, such undisturbed natural systems apparently did not exist in the real world; fire interrupts such successional trends at intervals related to the fire regime involved. Disturbance by fire or other factors can either speed up succession or set it back, depending on which species of a stand are attacked by wind, fire, insects, or disease. It appears that the ever-changing, fire-created mix of successional stages, communities, and stand ages in the vegetation mosaic of most wilderness forests is somehow essential to the stability of the system as a whole (Loucks 1970; Wright and Heinselman 1973b; Heinselman 1978).

Some different points of view recently presented in the ecological literature concerning stability, diversity, and resilience (Holling 1973; May 1973; Botkin and Sobel 1975; Orians 1975; Westman 1978) have been reviewed elsewhere (Kilgore 1981). Two main points were that (1) a static stability concept, borrowed from classical physics, may be inappropriate for the analysis of ecosystems because such natural undisturbed ecosystems "... are likely to be continually in a transient state" (Holling 1973); and (2) population stability in the natural world is not uniformly associated with trophic complexity and faunal and floral diversity. On the contrary, May (1973) noted that a number of natural monocultures, such as *Spartina* marsh grass, are very stable, and that instability comes not from simplicity, but from unnaturalness. He even contended that as a mathematical generality, increasing diversity and complexity enhance community instability. But he also agreed that we need much better understanding of principles that govern natural associations of plants and animals, something that can be gained primarily from studies of pristine ecosystems in wildernesses and National Parks.

ADOPTION OF RESEARCH RESULTS BY MANAGERS

Fire management on wilderness units of National Forest and National Park lands has come a long way in the past two decades. Just 17 years ago, in 1968, largely based on ecological research findings of the past 50 years, the National Park Service modified its policy of immediate suppression of all fires, which had been standard practice since the late 1800's. The Forest Service also began allowing lightning-caused fires to play a more natural role in wilderness in 1970, and in 1971 exceptions to the 10 a.m. (total suppression) policy were authorized when approved by the Chief of the Forest Service. This gradual revision of policy (see Kilgore 1976, 1982) culminated in early 1985 in a policy revision whereby Forest Service-ignited prescribed fires are allowed in wilderness under certain conditions. The broad research basis for such changes in policy and programs was reviewed earlier (Kilgore 1976).

One of the important aspects of the new Forest Service policy is use of prescribed fire to reduce unnatural buildups of fuels when this is necessary to meet the two objectives of fire management in wilderness. These two objectives are to (1) "permit lightning-caused fires to play, as nearly as possible, their natural ecological role within wilderness"; and to (2) "reduce, to an acceptable level, the risks and consequences of wildfire within wilderness or escaping from wilderness." (USDA 1985). Thus, Forest Service personnel will only ignite fires where—because of past fire suppression—lightning-caused fires alone cannot achieve wilderness management objectives. Thus before using prescribed fire, wilderness managers need to be sure the fire danger in a given area, as a result of fire suppression, is greater than would have existed had fire been allowed to occur naturally during the past 50 to 70 years. As such, criteria are needed to aid managers in judging when and where prescribed fire would be appropriate.

Since the early 1970's, fire management programs in the United States have expanded rapidly in National Parks and formally designated National Forest wilderness areas (Kilgore 1982). Similar programs are being considered for national parks in Canada (Lopoukhine 1985) and conservation reserves in Australia (Good 1981). Major programs of research on ecological effects of fire in South Africa (Huntley 1978) seem to provide the scientific basis for similar programs in national parks and reserves in that country.

By 1983, sufficient interest in programs involving natural fires and prescribed fires in wilderness and parks had developed that an entire symposium and workshop was held, in Missoula, MT, to discuss various implications of wilderness fire research and policy. More than 700 participants attended this 4-day session from Australia, Sweden, and all parts of the United States and Canada.

Success Stories

Lightning-caused fires are allowed to burn on 7 million designated acres in 16 areas managed by the National Park Service and on 9 million designated acres in 18 National Forest Wildernesses. Since the beginning of these programs, more than 1,200 lightning-caused fires have been allowed to burn about 190,000 acres of National Parks and National Forests. In addition, more than 840 planned prescribed burns were ignited in 26 national park areas covering some 180,000 acres (Kilgore 1982). Benchmark wilderness fire management programs are found in Sequoia-Kings Canyon, Yosemite, Everglades, Yellowstone, and Grand Teton National Parks and the Selway-Bitterroot, Gila, and Teton Wildernesses of the National Forest System.

Sequoia-Kings Canyon and Yosemite National Parks.—Early research by Weaver (1943) and Biswell (1967) in ponderosa pine forests provided important background understanding of the role of fire in the frequent, low-intensity fire regime vegetation. Subsequent research publications by Hartesveldt (1964), Biswell and others (1966, 1968), and Park Service scientists (Kilgore 1973a, Parsons 1978) pointed out the threat to mature sequoias by continued suppression of all fires. These

studies combined with the 1963 Leopold Report led to a three-part fire management program, the first of its kind, which:

1. Allowed lightning-caused fires to burn under prescribed conditions in designated areas where previous suppression had not had major impacts on fuel loading or plant succession/forest structure and when such fires do not threaten human life or property.
2. Used prescribed fires where unnaturally high fuel loads have accumulated following years of suppression and along boundaries.
3. Continued aggressive suppression of wildfires in developed areas where human life and property damage are major concerns.

To provide the additional information needed to support such a program, emphasis was given to studies of the role of fire in both high-elevation California red fir/lodgepole pine forests and low-elevation chaparral as well as the better known, lower elevation giant sequoia-mixed conifer forests. Research publications by National Park Service and Forest Service scientists (Agee, Kilgore, Parsons, Sando, and van Wagtendonk) and university scientists (Biswell, Bonnicksen and Stone, Hartesveldt, Harvey, and Rundel) provided a strong data base that was used by resource managers (Bancroft, Botti, Briggs, Nichols, Partin, and Riegelhuth) in preparing fire management plans for these parks (Bancroft and Partin 1979; Botti 1979). More than 87 percent of these two parks (1.4 million acres out of 1.6 million acres total) is included in natural fire zones, within which some 450 lightning fires have been allowed to burn nearly 40,000 acres in the first 15 years of the program (Kilgore 1982). In addition, nearly 150 prescribed fires, covering another 40,000 acres, have been ignited by National Park Service personnel. By nearly all standards, these programs are perceived to be a success, but recent studies have raised questions about whether more specific vegetation objectives are needed to achieve presettlement forest structure prior to further use of prescribed burning (Bonnicksen and Stone 1982a,b; Bonnicksen 1985; Parsons and others 1986). Such additional studies may help improve the quality of fire management in these parks.

Selway-Bitterroot Wilderness.—The White Cap Fire Management Area in the Selway-Bitterroot Wilderness in Idaho was the first approved exception to the Forest Service 10 a.m. (total suppression) policy. This exception was approved in 1972. In a pioneering joint research and management effort, fire management prescriptions were written for each vegetative management zone of the 100-mi^2 area (Mutch 1974). Special guidelines were developed by Forest Service researchers and managers for planning and inventory procedures (Aldrich and Mutch 1973). Other research support came from Habeck's studies of fire history, vegetation, and fuels in the Selway-Bitterroot (Habeck 1972, 1976).

The first major test of the White Cap plan was the 1,200-acre Fitz Creek Fire in 1973 (Mutch 1974). Although the fire spotted outside the approved fire management area and had to be suppressed on that side, the experiment was successful and led the way toward incorporating fire management considerations into wilderness planning generally in the Forest Service. Between 1974 and 1979, additional fire management plans were developed for various units of the Selway-Bitterroot Wilderness. The Independence Fire of 1979 burned more than 16,300 acres during a 3-month period, the largest fire allowed to burn under a natural fire program by any agency (Keown 1980, 1985a). By 1982, more than 1 million acres of the Selway-Bitterroot Wilderness were covered by plans that allow lightning-caused fires to play a more natural role. During the first 10 years of the program, 76 lightning fires have been allowed to burn nearly 39,000 acres (Kilgore 1982).

Grand Teton and Yellowstone National Parks and the Teton Wilderness.—Natural fire management programs on the Grand Teton and Yellowstone National Parks in Wyoming began in 1972. During the first decade of this program, more than 130 lightning fires were allowed to burn more than 38,000 acres. Among these were 13 large fires ranging from 160 to 7,400 acres in size (Kilgore 1982).

Studies of fire history and fire effects on various aspects of different ecosystems by Taylor (1969), Houston (1973), Loope and Gruell (1973), Sellers and Despain (1976), Despain (1982), and Romme (1982) served as the site-specific data base to support fire management plans for these areas. This basic information was extremely important to National Park Service managers in 1974 when the Waterfall Canyon Fire attracted much public attention to the whole concept of allowing lightning fires to burn in Parks and Wildernesses. This 3,500-acre fire also stimulated controversy about impacts of smoke on both National Park visitors and nearby communities. Air quality concerns must be met through smoke management criteria in current fire management plans; past and future research and monitoring can also play important roles in meeting this need (Ferry and others 1985).

One of the largest natural fire areas in the United States became operational in 1982 with approval of the revised Teton Wilderness Plan. Wilderness segments of Yellowstone and Grand Teton National Parks are coordinated in a more than 4-million-acre prescribed natural fire program with designated natural fire areas in the adjacent National Forest System Teton, Washakie, North Absaroka, and Absaroka-Beartooth Wildernesses (Kilgore 1982). Fire on National Park lands is allowed to cross the boundary onto National Forest lands, and fires on any of the forest wildernesses would be allowed to cross into Yellowstone and Grand Teton National Parks. While there has not yet been a test of how this interagency fire management concept will work, such opportunities will present themselves in the future. Agency researchers, both biological and sociological, would do well to help monitor the results of any such fires and the associated public reactions.

Everglades National Park.—The earliest exception to the total fire suppression policy in National Park Service areas was Everglades in Florida, where in 1951 Research Biologist Dr. William Robertson, Jr., began a study of the role fire plays in maintaining south Florida slash pine forest (Robertson 1953; Kilgore 1976). This work

was followed in 1958 by experimental research into prescribed burning as a means of controlling the hardwoods. Other scientists found that fire was also essential to maintaining stability of saw grass glades. As mentioned earlier, the Southeast had been far ahead of the rest of the country in recognizing the major changes brought about by removal of the fire process, particularly from their fast-growing pine ecosystems. The primary research at Everglades that supported the management decision to continue prescribed fire to maintain pineland forest was that of Robertson (1953 and his long-term unpublished study, cited in Taylor and Herndon 1981), Hofstetter and Parsons (1975), and Craighead (1971, 1974).

Remaining Opportunities

Despite these successes, there are also many areas for improvement. One prime example would seem to be the Boundary Waters Canoe Area (BWCA) of Minnesota. No place in the country has a better fire history record than the BWCA as a result of the truly remarkable studies of Heinselman (1973) augmented by those of Swain (1973). Plans were made in 1976 for introducing random ignition prescribed fires within the BWCA on a pilot basis, but apparently these were never implemented because of expressed need for more planning. Two problems that Alexander and Dubé (1983) noted as being unique to using fire in northern ecosystems are lack of defensible boundaries and the typical high-intensity crown fires.

Better Use of Fire History Data.—Another important opportunity exists for wilderness and park managers to make better use of fire history data and historic vegetation patterns prior to developing fire management plans for their unit. Experiences on two recent well-known prescribed fires—Mack Lake and Ouzel (see Kilgore 1982)—led to the conclusion that had the managers in charge of those fires been aware of specific past fire history in those two areas, they each could have made far better judgments and saved major costs (and perhaps a human life in one instance).

Better Use of Fire Weather Data.—Another opportunity exists for managers to make better use of fire weather forecasts and related burning indices. Postburn reviews of three prescribed fires (Mack Lake, Ouzel, and Seney, in Kilgore 1982) indicate that some of the problems encountered could have been ameliorated by more effective use of past weather records through computerized programs like RXWTHR and RXBURN (Bradshaw and Fischer 1981) and more effective use of related burning indices through the National Fire-Danger Rating System (Deeming and others 1977).

Incorporation of Research Results Into Management Practices.— In some instances, research results are not being incorporated into management practices quickly enough—both in the United States and elsewhere. Considerable insight into the role of fire in various ecosystems in Australia, Africa, and Canada, for example, is available through reporting of research findings in recent books, symposia, and other publications (Rowe and Scotter 1973; Huntley 1978; Schirge and Penderis 1978; Alexander 1978, 1979, 1980; Tande 1979; Hawkes 1980; Gill and others 1981; Alexander and Dubé 1983; Wein and MacLean 1983). And yet, no natural fire management plans or programs seem close to implementation in national parks or wilderness units in these countries. Even in well-established programs, new research findings about impacts of fire will be useful in reevaluating current fire management practices. Agency management personnel must always remain flexible enough to carefully consider new information. And researchers must be willing to define the limits of applicability of their data so as not to redirect policy based on flimsy research evidence. The overall goal must always be to restore natural processes and natural conditions to national parks and wilderness units, rather than a stubborn commitment to particular past techniques of achieving that goal.

CONFLICTING KNOWLEDGE AND UNRESOLVED ISSUES

In my judgment, the following are several of the key unresolved issues in wilderness fire management.

How Much Impact has Fire Suppression Had on Fire Regimes and Ecosystems?

The absence of fire for the past 50 to 100 years may have resulted in two primary changes in a forest or other vegetation that should be of concern to the wilderness manager: (1) It may have allowed accumulation of unnatural levels of fuels, or (2) it may have caused modification of species composition, age structure, or of horizontal or vertical forest structure beyond the range found in presettlement forests (Kilgore 1981).

Unnatural Fuels.—The question of unnatural fuel levels was addressed recently by Habeck (1985), van Wagtendonk (1985), and Brown (1985). In short-fire-return-interval ecosystems, where fires occur every 10 years or so, lack of fire for a 50- to 100-year suppression period could allow accumulation of fuels to an unnatural level. By contrast, in long-fire-return-interval ecosystems, where natural fire cycles range from 100 to 500 years or more, fire suppression for the past 50 to 80 years has probably not affected these ecosystems greatly. Brown (1985) wonders if the whole concept of whether fuel buildups are natural or unnatural is important. He urges, instead, that we focus our attention on forest structure—and specifically ". . . maintaining a natural balance of successional stages."

Relatively few studies have been undertaken specifically on the question of unnatural buildup of fuels as a result of fire suppression. The prime fire regime for such studies would be the frequent, low-intensity regime. The few studies to date have been carried out in the sequoia-mixed conifer forest (Parsons 1978; Parsons and DeBenedetti 1979).

Changes in Forest Structure.—Forest structure is often divided into four conceptual aspects: age structure, species composition, horizontal structure or mosaic pattern, and vertical structure or fuel ladders (Kilgore 1981). Each of these aspects can be modified by fire exclusion. The same three authors who discussed fuel accumulation at the Wilderness Fire Symposium also addressed the

question of changes in forest structure as a result of fire suppression. In the frequent, low-intensity fire regime, lack of fire has allowed shifts in species composition from sun-loving pine to more shade-tolerant true fir and related changes in mosaic patterns and vertical fuel ladders (Kilgore and Sando 1975; Bonnicksen and Stone 1982b; van Wagtendonk 1985) as well as changes in age composition of the various mixed conifer species (Kilgore and Taylor 1979; Parsons and DeBenedetti 1979). Brown (1985) suggests, "Mosaics of successional stages offer a more fundamental and reliable basis for determining naturalness than do fuel buildups." Such changes in fuel and forest structure may not be apparent in the long-return-interval fire regimes (Habeck 1985). One might reason, however, that stopping mosaic recycling by low-intensity understory burning for 60 years in an ecosystem with both frequent low-intensity fires and a 150-year cycle of stand-replacing fire does disrupt the vegetation mosaic, especially the proportion of young successional communities.

The relatively few studies of changes in forest structure as a result of fire suppression have been carried out in ponderosa pine forest (Weaver 1943, 1974; Cooper 1960; Lunan and Habeck 1973), sequoia-mixed conifer forest (Kilgore 1973a; Vankat and Major 1978; Kilgore and Taylor 1979; Parsons and DeBenedetti 1979; Bonnicksen and Stone 1982b), and other montane forests (West 1969). Major structural changes because of fire suppression noted in these studies have been: (1) a large increase in the younger age classes of pine in ponderosa pine habitat types (potential climax) and shade-tolerant white fir (in sequoia-mixed conifer forests); (2) survival of saplings beneath mature trees (in ponderosa pine forests) and one or more vertical layers or tiers of white fir beneath the overstory canopy of sequoia and pine (in sequoia-mixed conifer forests) providing ladder fuels that can lead to high-intensity crown fires; (3) many more trees per acre, particularly young shade-tolerant saplings; (4) a blending of what had been discrete patchy units into a more uniform forest, with more uniform burning intensities, gradually destroying the identity of individual even-aged groups or aggregations found in presettlement times.

Work is just beginning on the impact of fire exclusion on other vegetation types, particularly those Rocky Mountain forests involving mixtures of lodgepole pine, Douglas-fir, ponderosa pine, and larch in which a variable regime of frequent low-intensity surface fires alternates with long-return-interval, stand-replacing fires. The question to be answered here, is: has suppression of the low-intensity fire portion of this regime caused sufficient fuel buildup or changes in forest structure to cause significantly different results when a high-intensity crown fire burns through? Even in ponderosa pine and sequoia-mixed conifer forests, quantifying the changes caused by fire exclusion has just begun, and there is need for better information.

In the meantime, however, philosophical and policy questions have also been raised about the appropriateness of restoration efforts, and whether wilderness and park managers should (1) simply allow natural fires to burn; (2) reduce obvious fuel accumulations in certain zones with prescribed fires and then allow natural fires to burn; or (3) carefully restore natural structure to estimated presettlement conditions before allowing natural fires to burn (Bancroft and others 1985; Bonnicksen 1985; Kilgore 1985a; Lucas 1985; Worf 1985; Bonnicksen and Stone, in press; Parsons and others 1986). Graber (1983) has recently speculated on the proper role of National Park natural areas as ecosystem preserves. While allowing natural fires to burn has a broad philosophical appeal, it has drawbacks as well. In presettlement times, many lightning fires spread from areas outside present wilderness. In addition, some lightning fires currently ignited in wilderness will be suppressed. Hence, the more complex options need to be carefully evaluated.

How Important Were Aboriginals as Ignition Sources?

A recent review of the role of American Indians in the fire history of North American ecosystems makes clear that these peoples burned for many reasons, "including signaling, food gathering, hunting, forage and animal population management, vegetation management, maintenance of habitat diversity, and warfare" (Dennis and Wauer 1985). Such burning was done in different frequencies, intensities, locations, and seasons, and, as a result, the effects of such burning varied greatly from place to place (Gruell 1985; Lewis 1985; Arno 1985; Phillips 1985). It appears that Indian fires were of considerable significance in grassland, shrubland, and certain lower elevation forest types for at least a thousand years before European settlement (Arno 1985). Such fires, however, were not as common in upper elevation forests.

While some additional site-specific information gathered through research may be needed to understand how to simulate the role of Indian burning in a particular vegetation type or geographic area, we have considerable knowledge of this subject for most areas of North America and some parts of Australia. The more significant policy question is whether or not we want to restore Indian burning. During the 1983 Wilderness Fire Symposium, a workshop dealing with the role of Indian burning in wilderness concluded that development of additional philosophy and policy is needed to support future decision-making regarding whether wilderness managers should try to simulate Indian burning (Dennis and Wauer 1985). Because wilderness and park units are unique, with specific management needs, the workshop felt a blanket policy should not be adopted that would override site-specific characteristics and needs of individual areas.

Considerable concern has been expressed recently that simulating Indian burning would permanently implant our subjective judgment on when to ignite fires as well as freeze Indian culture at a point in time. Graber (1983) proposed instead that the National Park Service adopt "the unimpeded interaction of native ecosystem processes and structural elements" as the principal aim for park natural areas. Exceptions to this basic resource management goal would need to be explicitly stated and justified in plans for each area.

What Is "Natural" in Wilderness Fire Management?

While the term "natural" is often used in statements of goals or objectives for wilderness fire management programs, it does not yet have a common meaning in the literature of fire ecology or wilderness fire management. Researchers and managers of the earliest natural fire management program in the United States say that a prime need for their future programs is to define what is "natural" (Bancroft and others 1985).

The working definition developed for the 1983 Wilderness Fire Symposium, involving both the fire process and the resulting effects, was that:

> A natural fire for any given ecosystem (1) burns within the range (and frequency distribution) of fire intensities, frequencies, seasons, and sizes found in that ecosystem before arrival of western technological man, and (2) yields the range of fire effects results found in that ecosystem before the arrival of technological man (Kilgore 1985b).

There are four actions that may help clarify the meaning of "natural" in wilderness and park fire management programs:

1. Initiate quantitative research aimed at better defining changes in fuels and forest structure resulting from fire suppression during the past 50 to 100 years.
2. Initiate research to better characterize the fire regimes under which an ecosystem evolved. This should emphasize any role that high-intensity, stand-replacing fires may have played in presettlement times.
3. Using this information, develop an appropriate policy/philosophy decision process—involving value judgments rather than technical expertise or research—to decide (a) whether efforts will be made to restore community structure as it occurred at some given point in time, before fire will be allowed to interact with that structure to produce a "natural" ecosystem (Bonnicksen 1985), or (b) whether, instead, emphasis will be placed on the function of fire, not the structure of the ecosystem, and fire will be allowed to simply burn within the existing ecosystem structure or after fuels have been reduced. This assumes that structure would not be so different from conditions that have occurred at some point in the past as to be strongly detrimental to a "natural" outcome (Bancroft and others 1985; Parsons and others 1986).
4. Use the same decision process—and considerations raised by Graber (1983)—to decide whether or not Indian fires are to be considered "natural" and to be mimicked.

Large, High-Intensity, Stand-Replacing Fires in Wilderness

Two unresolved questions are: (1) Can we allow some of these crown fires to burn in certain wilderness units? and (2) should we do so? The first is a technical question subject to interpretation and conclusions using fire effects, behavior, and history data gathered by research. The second is a policy/philosophy question that makes use of such technical information, but relies heavily on value judgments for the answer. These fires occur in ecosystems involved with fire regimes 4, 5, and 6, where large, high-intensity, stand-replacing fires occurred at intervals ranging from 50 to 500 years or more. Managing wilderness fire programs involving such crown fires poses difficult fire control and human safety questions as well as complex ecological alternatives (Kilgore 1982; Heinselman 1985; Mutch and Davis 1985).

In his detailed review of this question at the 1983 Wilderness Fire Symposium, Heinselman (1985) lists five regions involved with such fire regimes:

1. The Great Lakes forest in Canada and the United States;
2. The New England and Acadian pine and certain spruce-fir forests;
3. The Canadian and Alaskan boreal forest;
4. The Rocky Mountain subalpine and upper montane zones from Alberta to Colorado and Utah; and
5. The Douglas-fir region of the Pacific Northwest.

In evaluating these fire regimes and regions, he notes that an important question is whether we can predict which stands will ignite readily and sustain crown fires if we know such things as stand age, species composition, and time since last fire. The answer depends on the local situation and on a better understanding of crown fire behavior than we now have, although some good work has been done (Van Wagner 1977, 1978; Albini 1979; Rothermel 1983). A similar question is whether we can predict potential maximum fire paths in a given area. One way that should not be ignored in developing management units in a natural fire management plan is to emphasize fire history, vegetation patterns, fuel loadings, aspect, and drainages where unusual fire behavior may be expected, because fires have a way of repeating themselves (Kilgore 1982; Heinselman 1985). Both the Ouzel Fire in Rocky Mountain National Park in Colorado in 1978 and the Mack Lake Fire in Michigan in 1980 tended to follow patterns of previous fires in the same area, but managers were apparently not aware of these patterns (Laven 1979; Simard 1981a).

In surveying fire experts concerning the meaning of "natural," I asked their impressions of how to handle high-intensity fires where these were found to be part of the presettlement fire history of a given ecosystem. A large majority philosophically favored letting such high-intensity fires burn, but nearly all added caveats to protect human life and property and avoid going beyond park and wilderness boundaries (Kilgore 1985b). Most felt an initial program of prescribed burning was desirable for fuel reduction. There was a sizable minority that felt either high-intensity crown fires are too hazardous to be acceptable, or that the areas in parks and wilderness are too small to accept this type of fire.

The questions of whether we can and should allow high-intensity fires to burn, therefore, remain to be answered. Only certain sizable areas, like Yellowstone National Park, WY, have allowed such fires to burn thus far. Perhaps there are a few other sizable wilderness and park units where this would be acceptable; small-sized units obviously must be ruled out. It would appear that instead of simply allowing such severe fires to burn,

there is a greater willingness to consider using prescribed fire and perhaps "crowding" the prescription in a way that we might get results close to high-intensity, stand-replacing fires, but without the threats to human life encountered now by simply waiting for the inevitable wildfire. The alternative of total suppression has its drawbacks, as well, in that consequent fires will almost always burn under the worst possible fire control conditions, with high suppression costs and accompanying threats to human life and property.

DIRECTIONS FOR FUTURE RESEARCH

Needs for future research can be divided somewhat arbitrarily into technique needs and new information needs. Here is a brief listing of the higher priority wilderness fire research needs for the next decade.

Techniques/Methods Research

1. **Develop criteria by which managers can judge whether an ecosystem has been impacted in a major way by past fire suppression/exclusion.** Emphasis should be on ecosystems with intervals between fires considerably shorter than the duration of fire suppression efforts. Criteria must provide a way of judging changes in (a) fuels and (b) forest structure. They need to have a significance measure such as: Will the new level of fuels or patterns of forest structure lead to crown fires in ecosystems and fire regimes where they were not characteristic in presettlement time?

2. **Develop minimum impact methods for determining fire history in wilderness and park ecosystems.** This must include (a) interval between fires at a given site or stand; (b) fire intensity or severity; (c) size or areal extent of past fires; and (d) season of presettlement burning.

3. **Develop cost-effective techniques for restoring natural conditions over extensive areas of a wilderness or national park and demonstrate these methods.** Various combinations of manager-ignited prescribed burns and natural (lightning-caused) ignitions can be proposed and tested to determine the most efficient and effective ways of restoring both natural conditions and natural processes to ecosystems that have been impacted in major ways by man-caused fire exclusion.

4. **Develop standard techniques to help managers monitor performance of their wilderness fire plan.** Procedures for monitoring and evaluating natural fires and prescribed fires are needed for various forest ecosystems to enable researchers and managers to compare a planned fire regime to a "natural" fire regime in these ecosystems and to determine how well managers are implementing the plan and achieving their goal and objectives.

5. **Develop the capability to predict August behavior of natural fires ignited in July in wilderness areas.** These would probably be in the form of climatological probabilities to aid managers in decision making for long-duration lightning-caused fires.

6. **Develop special techniques for simulating the natural role of fire in wilderness areas where allowing natural (lightning-caused) fires to burn is impractical and where ignitions outside the wilderness no longer burn into the wilderness.** This will require using manager-ignited prescribed fires at frequencies, intensities, and seasons found in the presettlement period, to provide a close approximation of the natural fire history, behavior, and effects, but at the same time ensuring safety for human life and property. As an example, Pinnacles National Monument in California will use primarily prescribed (planned ignition) fire in legal wilderness (Agee and others 1980).

New Information Needs

1. **Using the best data available, determine what are the "natural" fire history, fire behavior, and fire effects for key short-return-interval wilderness ecosystems.** This will require using techniques developed above and an analysis of the existing range of fuel accumulations and forest structure patterns based on the expected range of fire frequency, intensity, size, and season. Judgments could then be made of how close to "natural" a given situation is.

2. **Document by case studies in key short-return-interval ecosystems how significantly current conditions depart from "natural" in terms of fuels and forest structure.** As an example, in a seral pine/larch/fir forest, knowing the mean and maximum intervals between fires in presettlement times, a researcher might check ages of young shade-tolerant species coming in under overstory canopy to determine what proportion exceed the historic maximum interval between fires. Current species composition of young shade-tolerant species might also be compared with similar composition in presettlement forests. Measurements would also be needed to check horizontal mosaic patterns, vertical forest structure (fuel laddering), and levels of ground, surface, and dead and living aerial fuels.

3. Through careful study and analysis of the results obtained from research priorities No. 1 and 2 above, **decide how precise we must be in restoring fuel levels and forest structure to key short-return-interval ecosystems before we allow natural forest to burn again.** In the sequoia-mixed conifer forests, for example, some researchers advocate fairly tight quantitative standards for restoration of vegetative aggregations found as part of a horizontal mosaic pattern in that ecosystem (Bonnicksen 1985), while some managers feel simply allowing natural fires (lightning-caused) to burn again in all ecosystems is best (Worf 1985). I tend to see a middle ground where prescribed fire could be used to reduce unnatural fuels and ameliorate major changes in forest structure (Kilgore 1985a), but without the precision suggested elsewhere (Bonnicksen and Stone 1982b). Managers are wrestling with these concepts and tend toward a conservative management strategy of "minimum intervention" (Bancroft and others 1985). These are difficult decisions, and research in the very near future could play an important role in clarifying the best way to achieve the common goal. That goal is to let "natural processes operate as freely as possible while minimizing the impacts of human actions—past and present—on wilderness ecosystems" (Kilgore 1985a).

4. In National Park and wilderness ecosystems where managers decide that Indian burning was part of the "natural" presettlement fire regime, **additional research may be needed on the relative importance of such aboriginal ignitions and lightning in determining intervals between fires and both intensities and severities of fire.** The difficult question of evolution of Indian culture will need careful consideration. Where appropriate, such information can then be utilized by managers in seeking to mimic the results of Indian burning through scheduled prescribed burns.

5. **Determine whether scheduled fairly high intensity prescribed burns can approximate the ecological effects of high-intensity, stand- replacing fires** (where these are part of the natural fire regime in wildernesses and National Parks) **under burning conditions less explosive than those characteristic of many such natural crown fires.** Only a few large wilderness units can ever hope to allow some of these high-intensity fires to burn. Few researchers have attempted to experiment with crown fire behavior and effects to date (Van Wagner 1977). Perhaps fire managers and researchers in the next decade can find ways to provide periodic stand renewal by prescribed burning without losing control of such fires (Alexander and Dubé 1983; Heinselman 1985).

6. **Determine fire effects relationships to habitat needs of endangered wilderness wildlife species such as the grizzly bear.** For example, fire is known to encourage growth of huckleberries (*Vaccinium* spp.), which are important seasonally in the diet of the grizzly. How much of the whitebark pine (*Pinus albicaulis*) type is seral and fire dependent, and what role does fire play in stimulating the pine nut crop, also apparently a staple food item for some grizzly populations (Kendall 1980)?

7. **Determine how suppression of fire has impacted key insect and disease populations in certain forest types through changes in age structure, species composition, and mosaic patterns of the forest.** Only through a better understanding of the natural interaction between forests, fires, key insects, and diseases can we understand how exclusion of fire may have made major ecosystem changes that encourage growth of insect and disease populations. Such ecosystem changes, in turn, may require that we modify the unnatural structural factors by subsequent prescribed fires to help restore a more natural ecosystem.

CONCLUSIONS

We know a great deal about fire in many ecosystems and fire regimes. Yet there is much more to learn. The next 10 years may well be the Decade of Wilderness Fire as Pyne (1985) contends. Most of the fire plans will be completed and the management decisions will be made. It, therefore, behooves us as researchers and resource managers to work closely together to seek to clarify our goals and objectives. While there are various interpretations of what Starker Leopold and his committee meant by some statements in the 1963 Leopold Report, the general philosophy is still clearly expressed in the admonition, "Above all other policies, the maintenance of naturalness should prevail!" While not easily or precisely defined, it is nevertheless imperative that the results of all our efforts take us as close to that ideal as possible—the ideal of allowing natural processes, including fire, to function unimpaired in National Park and wilderness ecosystems.

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AIR QUALITY AND WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

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ABSTRACT

Air quality is an important component of the wilderness concept. In wildernesses that are designated Class I lands, "air quality-related values" are protected by the Clean Air Act and its amendments. In addition, all wilderness, as defined by the Wilderness Act, is to be protected and managed so as to preserve its unique character, including its air resource. This paper provides an overview of the air quality legislation pertaining to wilderness, a brief summary of the types of air quality conditions potentially affecting wildernesses, and a discussion of research efforts that have addressed air quality and its influence on aquatic and terrestrial ecosystems. A limited survey of Federal land managers responsible for wilderness areas provides insight to the current ecological understanding, research, and information needs required to adequately protect and maintain these primitive areas. The authors suggest that a well-developed system of air quality-related values applicable to wildernesses is critical for proper protection.

INTRODUCTION

Congress has defined "wilderness" in the Wilderness Act of 1964 (Public Law [PL] 88-577) as "...an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain..." and "an area of undeveloped Federal land retaining its primitive character and influence, without permanent improvements of human habitation, which is protected and managed so as to preserve its natural conditions...." Implied in this definition is the preservation of a very transient but vital component of the wilderness—its air quality.

Earlier papers in this conference have discussed various values of wildernesses. These values, for the most part, include those characteristics associated with pristine conditions. Maintaining the pristine condition of air quality in wildernesses may be impossible. Even in the most remote regions of the world, evidence of contamination by global circulation of airborne pollutants has been found (Davidson and others 1985). For example, the long-range transport of acidifying pollutants from England and central Europe and subsequent ecological effects in Scandinavia are well documented. Although development affecting air quality can be controlled within wildernesses, control of outside development that contributes to a degradation of air quality is only partially successful. The Clean Air Act and its amendments protect some wildernesses and portions of others only from certain kinds of emission sources. Wilderness areas are currently affected by regional air pollution such as acid rain or oxidants. Control of these pollution sources when air quality and other wilderness components are observed to be adversely affected is a major point of controversy and discussion (for example, OTA 1984).

Air quality is influenced by both natural and human-made sources. Natural events such as forest fires, volcanic eruptions, geothermal activities, and biogenic sources can lower air quality in wildernesses. Forest fires can contribute locally and regionally significant amounts of particulates, carbon dioxide, and hydrocarbons (Smith 1981). The major influence on air quality in most of these areas, however, is from human-made sources. A number of air pollutants have affected, or are suspected to affect, wilderness conditions. These can be grouped into three major types: photochemical oxidants, including secondary pollutants such as ozone; particulates, such as trace elements, organic compounds, and radioactive particles; and acidifying pollutants, including the primary gaseous emissions such as sulfur dioxide and nitrogen oxides (Peterson and Adler 1982). The origin of these major pollutant types can be point sources (for example, industrial facilities such as powerplants and smelters) or nonpoint regional sources (such as urban areas, industrial complexes, and mobile sources related to transportation). The effects of air pollution can be composed of either single or multiple factors. Multiple effects can involve pollutant-pollutant interactions as well as pollutant-natural stress factor considerations, such as dramatic insect population changes.

The components of wildernesses that can be affected by air pollution include whole ecosystems (lake acidification); certain properties of ecosystems (nutrient cycling); and the biotic and abiotic components of ecosystems (plants and soils). Air pollution can also affect multiple ecosystems such as the lakes and forests around Sudbury, ON, Canada, which have been impacted by emissions from a large smelter.

Our purpose is to provide a brief overview of past and present air quality legislation and research related to the protection and management of wildernesses. In addition, we will identify some major air quality wilderness research themes for the future.

In preparing this overview we have relied on a number of studies demonstrating key wilderness-air quality issues as well as summaries that review ecological effects of air pollution relative to various wilderness components. For example, Smith's book, *Air Pollution and Forests* (Smith 1981), the U.S. Fish and Wildlife Service's series on air pollution and acid rain, the U.S. and Canadian Working Group report on transboundary air pollution, and the Environmental Protection Agency's critical assessment document of acidic deposition (Altshuller and Linthurst 1984)

each provide detailed discussion on air quality and its relationship to biological systems also found in wilderness areas. A number of major ecological research studies on air pollution, such as the Colstrip Project in Montana (Lauenroth and Preston 1984) and the Hubbard Brook Ecosystem Project in New Hampshire, have also contributed significantly to our understanding and appreciation of a whole system's response to air pollution. Manual and computer literature searches, focusing on references published since 1981, involved the following data bases: BIOSIS, NTIS, AGRICOLA, POLLUTION ABSTRACTS, ENVIRONLINE, and to a limited extent, SCISEARCH. *Ecological Abstracts* and the *Acid Precipitation Digest* were also manually searched. Halpin (1977) provides a good introduction to the air pollution literature. To complement this information, we conducted a limited survey of investigators and Federal agencies regarding air pollution research with application to wildernesses. Federal land managers of wilderness lands with special air quality protection (Class I) administered by the National Park Service, Fish and Wildlife Service, and Forest Service were contacted to determine ongoing or planned air quality-related research programs. Future research needs were also assessed.

AIR QUALITY LEGISLATION AND WILDERNESSES

The oil crisis of the early 1970's forced the Nation's attention on the tenuous availability of this supply of energy and pushed the development and use of our own fossil fuel resources. The role of fossil fuels in meeting the country's energy demands was projected to increase exponentially. This search for energy independence introduced a number of activities with impacts or potential impacts to wildernesses. In addition to the imminent threat of exploration and development in areas adjacent to wildernesses, the increased use of fossil fuels, particularly coal, accelerated atmospheric loading of combustion byproducts. Coupled with this type of airborne pollution were the continuing contributions of trace metals and other contaminants from smelting of metallic ores and the release of trace organics and other chemicals from various industrial processes (Soholt and Wiedenbaum 1981; Miller 1981).

The emissions from both point and nonpoint sources are capable of being carried long distances by prevailing winds and undergoing various chemical transformations in the process. This delivery system allows the transfer of toxic materials to surface receptors in wildernesses far removed from actual pollution-generating sites or regions. Research in Scandinavia focused attention on effects of a specific form of air pollution, a rediscovered phenomenon called "acid rain" (Drablos and Tollan 1980; Swedish Ministry of Agriculture 1982), and evidence was accumulating for similar impacts in the United States (Dochinger and Seliga 1976; Pfeiffer and Festa 1980).

It was in this time of environmental awakening in the 1960's and 1970's that a number of new pieces of legislation and revisions to old laws related to air quality were created. Incorporated in this important legislative activity was the concept of air as a resource requiring protection and the implementation of standards to maintain certain air quality standards in designated areas.

The Air Pollution Control Act of 1955 (PL 84-145, 69 Stat. 322), the Clean Air Act of 1963 (PL 88-206, 77 Stat. 392), and the Air Quality Act of 1967 (PL 90-148, 81 Stat. 485, as amended) were early attempts for regulatory action (Avery and Schreiber 1979). However, it was the 1970 Clean Air Amendments that provided the strong Federal role in establishing and enforcing ambient air standards. These amendments designated air quality control regions, provided air quality criteria and pollution control techniques information for major pollutants, and established primary and secondary National Ambient Air Quality Standards (NAAQS) for criteria pollutants. Criteria are issued to assist with decisions about the need for control of a given pollutant and for the development of air quality standards to govern the pollutant. Primary standards are those necessary for the protection of "public health"; secondary standards are those that provide a level of air quality that protects the "public welfare" from any known or anticipated adverse effects (Avery and Schreiber 1979). It should be noted that "public welfare" includes, but is not limited to, effects on soils, water, vegetation, animals, wildlife, and visibility—all values important to the concept of wilderness.

National air quality goals also involve Federal standards for control of airborne pollutants. For example, New Source Performance Standards (NSPS) deal with new stationary sources of emissions, such as powerplants. Title II legislation set standards for motor vehicle emissions and fuels and the National Emission Standards for Hazardous Pollutants (NESHAP) covered specific pollutants such as asbestos. The Federal land manager's role became one of complying with the standards and being involved with the permitting process for projects that might adversely affect the air resource.

Pollutants currently covered by the NAAQS include sulfur oxides, particulates, carbon monoxide, photochemical oxidants, nitrogen dioxides, and lead (table 1). A major share of the responsibility for meeting the goals of NAAQS is placed on the States by requiring their development of individual State Implementation Plans (SIP's). These plans address the timely attainment and maintenance of NAAQS. Areas that meet the standards (attainment) or that are unclassifiable are considered "clean air" areas. The SIP's require maintenance plans to assure no violation of NAAQS and plans to prevent any significant deterioration of these areas. The concept of prevention of significant deterioration (PSD) was implied in the 1970 amendments and became a major part of the 1977 amendments (PL 95-95, 91 Stat. 731, Part C). Significant deterioration is defined by the use of baseline levels and increments for criteria pollutants. The baseline level is the actual concentration that exists within the clean air areas at a fixed time and the increment is the additional concentration of an air pollutant that can be added to the area. The effect of the baseline-increment concept is that the PSD ceiling varies from place to place. The allowable increment in dealing with the PSD permit application, then, is the margin between baseline and the lower of either the

Table 1.—National primary and secondary ambient air quality standards

	Air quality standards			
	Primary		Secondary	
	Annual mean	Maximum concentration (allowed once yearly)	Annual mean	Maximum concentration (allowed once yearly)
	Micrograms/m^3			
Sulfur oxides (SO_x) (measured as SO_2)	80	365 (during 24 hours)	—	1,300 (during 3 hours)
Particulates	75	260 (during 24 hours)	60	150 (during 24 hours)
Carbon monoxide (CO)	—	10 milligrams/m^3 (during 8 hours) 40 milligrams/m^3 (during 1 hour)		Same as primary standard
Photochemical oxidants	—	160 (during 1 hour)		Same as primary standard
Nitrogen dioxide (NO_2)	100	—		Same as primary standard
Lead	—	1.5 (averaged over calendar quarter)		Same as primary standard

NAAQS or full increment. It is this component of the clean air legislation that has particular relevance to wildernesses. Under the 1977 amendments, lands were classified as one of three categories: Class I—where only minor air quality deterioration was permitted; Class II—where deterioration normally accompanying moderate, well-controlled growth was acceptable; and Class III—where a rise in pollution levels up to the NAAQS was considered acceptable (Avery and Schreiber 1979). Within this land classification scheme, wildernesses exceeding 5,000 acres (2 024 ha) and established before August 1977 were automatically designated Class I areas. Remaining wildernesses were assigned to Class II but were to be subject to possible redesignation. For wildernesses established after August 1977 and exceeding 10,000 acres (4 049 ha) the redesignation was limited to either Class I or II.

The Federal official managing these Class I areas has the "affirmative responsibility" to protect the air quality-related values (AQRV) and, along with the regulatory authority of the Environmental Protection Agency, to consider whether or not a proposed emitting facility will adversely affect those values (Avery and Schreiber 1979). Visibility is specifically addressed in the amendments, but other aspects such as acid rain and damage to flora and fauna are also considered under the term AQRV. The Federal land manager must therefore be knowledgeable of the air quality-related values on the Class I lands and their sensitivity to air pollution. Although wildernesses not currently designated Class I are not provided this protection under the Clean Air Act, the management requirements of the Wilderness Act may be interpreted to include similar restrictions. For example, in some Forest Service regions, to afford the best protection of air quality in wilderness areas, all wilderness is treated as if it is Class I so as to protect it from all human-made changes including air pollution (Haddow 1984).

These laws and standards demonstrate the importance of air quality to the general public and our growing concern for monitoring and protecting the air resource.

In 1969, the National Wildlife Federation (NWF) incorporated air, as well as other natural resources, as part of an index to annually assess the national environmental quality and to provide a subjective analysis of trends (Kimball 1969). Air pollution was considered the most serious threat to environmental quality in the first assessment. There was also an indication of a downward trend in air quality in spite of the fact that air pollution control laws existed in 46 of the 50 States at the time. By 1975, air quality had improved somewhat, the index had turned, and the trend was upward.

Ten years after the first NWF index there was evidence that the air was in fact cleaner due to the Federal Air Pollution Standards. Between 1975 and 1983 sulfur oxide emissions were reduced 19 percent, and air in general contained 36 percent less sulfur dioxide and 20 percent fewer suspended particles. Electric utilities had spent $67 billion on air pollution control, primarily to reduce sulfur emissions. Unfortunately, at the same time the increasing number of monitoring stations (2,000 in 1970 compared to 6,500 in 1975) provided evidence that air in rural areas was being further degraded. The transport of pollutants from urban point sources to remote areas eventually became one of the major concerns in the acid precipitation controversy of the 1980's. By 1977, damages to health from air pollutants were estimated at $10 billion annually, and visibility in some remote areas had declined as much as 20 percent. The first indications of problems with acid rain in remote areas such as the Adirondacks were coming to light at the same time economic growth had slowed and there were increasing prospects for relaxing current standards. By 1981, when the Clean Air Act was up for revision, the acid rain controversy was a major issue. Of particular concern was the damage or potential for damage in

remote pristine ecosystems such as the Nation's wildernesses. The current Clean Air Act is designed primarily to address local effects and does not effectively deal with long-range transport and transformation of air pollutants. With the growing body of research, including reports from the prestigious National Academy of Science (for example, National Academy of Science 1981), the public has expressed a continuing interest and support for strong regulatory controls for improved air quality. Although no decision has yet been made on the best way to control acid rain, the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act) established a Federal interagency task force to implement a comprehensive research program. The program's objectives are to identify the causes and sources of acid precipitation; evaluate environmental, social, and economic effects; and take action to limit or eliminate the sources and remedy the harmful effects (Interagency Task Force 1982). This 10-year National Acid Precipitation Assessment Plan (NAPAP) provides annual reports to the President and Congress and biannual assessments of the status of acid precipitation impacts on the Nation's resources. Provisions for Class I lands in the Clean Air Act and its amendments provide the only current legislation on acid rain.

AIR QUALITY BIOMONITORING AND WILDERNESS AREAS

As with other types of pollution, the need to collect information indicating the condition and trends in the health of ecosystems and their components exposed to air pollution has led to development and use of air pollution biomonitoring. Three types of air quality biomonitoring approaches are in use today and are part of monitoring in wildernesses: air quality-related values, bioindicators, and biosphere reserves. The first type is a biomonitoring approach, mandated by air quality legislation, while the latter two are general biomonitoring approaches using single species or whole ecosystems as biomonitors. As previously discussed, the Clean Air Act and its amendments of 1977 give special attention to potential ecological effects in Class I lands, which include certain wildernesses. The Federal land manager has responsibility to review PSD permits for new sources that may affect these areas and to determine whether or not adverse impacts on the AQRV's of that Class I area will occur. The Department of the Interior has defined AQRV's as being: "...all those values possessed by an area except those that are not affected by changes in air quality and include all those assets of an area whose vitality, significance, or integrity is dependent in some way upon the air environment. These values include visibility, and those scenic, cultural, biological and recreational resources of an area that are affected by air quality" (Federal Register 1978). Currently, AQRV's are being further refined by agencies such as the Forest Service and the National Park Service. For example, the concept of "adverse" effects has been defined by the Rocky Mountain and Intermountain Regions of the Forest Service as "change" rather than just "damage" (Haddow 1984). Specific AQRV sampling protocols for particular ecosystems (for example, at high elevations) are being developed by the Forest Service (see papers by Fox and Haddow in this proceedings).

When identifying Class I area AQRV's, visibility is the only value to date that has received formal attention and use of standard assessment techniques. Ecological AQRV's have been developed on a case-by-case basis as Federal land managers have been requested to review PSD permits. In 1981, the Forest Service held a workshop on identifying and protecting AQRV's of the Flat Tops Wilderness in Colorado (Fox and others 1981). Specific AQRV theory along with identification of specific AQRV's were presented. For fish and wildlife AQRV's a matrix approach was used to identify and develop wilderness monitoring programs (Newman and others 1981). A hierarchical progression of AQRV's was proposed based on societal significance, wilderness management needs, and special species consideration. Primary pollutant interaction points or potential points of contamination were identified and, using this matrix analysis of potential effects, appropriate biomonitoring programs were suggested. More recently, the Forest Service has identified a number of wilderness attributes as values that can be affected by air quality and from these they have developed a number of specific AQRV indexes (table 2) that can be impacted, that is, changed from their natural state (Haddow 1984).

The importance of establishing AQRV's has been indicated in several recent cases concerning Class I refuges and parks and the potential impact of new sources of emissions. For example, an aluminum smelter with fluoride emissions, potentially affecting Cape Romain National Wildlife Refuge in South Carolina, and a powerplant and natural gas processing facility with SO_2 emissions, potentially affecting Theodore Roosevelt National Park and Lostwood National Wildlife Refuge in North Dakota, have required AQRV reviews. After AQRV analysis no "adverse" impact determinations were given by the Federal land managers although, based on modeling, some potential impact was predicted for the most sensitive AQRV's—lichens (Federal Register 1982).

Air pollution bioindicators have been proposed and used for a long time. The first uses were to protect human health. Miners, for example, took canaries into the mines to detect carbon monoxide. Bioindicators are useful for several reasons: they are indicative of an ecological response to given air quality conditions, they can indicate trends in ambient air quality conditions, and they provide correlations between physical-chemical measurements and ecological effects.

Air quality bioindicators can be of several types (Newman 1980):

1. Sentinel organisms—highly sensitive species whose response can act as an early warning signal to a particular pollutant;
2. Bioassay monitors—species with known life histories and known characteristic responses to a given pollutant;
3. Detectors—species found in an environment that show a reasonably characteristic response to a given air pollutant (not as diagnostic as bioassay monitors);
4. Thrivers—species whose presence or abundance indicates the occurrence of a particular pollutant or environmental condition associated with a pollutant; and
5. Accumulators—species that collect and accumulate an air pollutant in detectable quantities, thereby showing trophic accumulation.

Table 2.—Wilderness attributes identified by the Forest Service that are impacted by air quality and suggested indexes for determining change (from Haddow 1984)

Attribute					
Flora/fauna	**Soil**	**Water**	**Visibility**	**Odor**	**Cultural, archeological, geological**
Growth	Cation exchange capacity	pH	Contrast	Odor	Decomposition rate
Mortality	Base saturation	Total alkalinity	Visual range		
Reproduction	pH	Metal concentrations	Coloration		
Diversity	Structure	Anion and cation concentrations			
Visible injury	Metal concentration				
Succession					
Productivity					

In contrast to water pollution monitoring, no hierarchical system of bioindicators has been developed for air pollution monitoring. Presently for air quality studies, plants are probably the most developed bioindicator group. Higher plants used in monitoring have involved species ranging from crops and ornamental plants to naturally occurring trees and weeds (Heck 1966; Minnesota Environmental Quality Board 1984). Field surveys of plants have been the most common bioindicator approach. In this situation knowledge of the sensitivity and recognition of the symptoms exhibited by particular plant species are required. A large number of plants are used in the survey, and selection is dependent upon the observer's experience and preference. The National Park Service is surveying more than two dozen park lands using the responses of milkweed (*Asclepias*), white pine (*Pinus monticola*), and ponderosa pine (*Pinus ponderosa*) as indicators of ozone effects (Bennett 1985b). In another approach, "indicator gardens" consisting of different plants with defined responses to various pollutants have been used. Minnesota, using this approach with native species and supporting fumigation studies, has established seven sites at diverse locations for long-term monitoring (over 10 years) of air quality. Use of isolines of a plant with varying sensitivities has also been proposed. The use of bioindicator gardens has a number of advantages, including the ability to be colocated with air monitoring stations. In addition, the accessibility to the natural occurrence of known sensitive species may be difficult. Establishment of indicator gardens with these species in accessible locations is possible (Bennett 1985a).

The most widespread and probably best understood plant bioindicator system involves the use of lower plants. Lichens and bryophytes have been used as air pollution indicators in North America and Europe (Ferry and others 1973; LeBlanc and Rao 1975; Skye 1979). Because of a number of characteristics, they are especially suitable as pollutant monitors. Specifically, they are evergreen and slow growing, and, having no roots, they derive all their nutrients from air and rainfall. Because they lack stomata, they do not have the ability to control gas exchange. Also, these groups cannot shed pollutant-damaged structures as higher plants can.

Field surveys and transplant studies are employed in using lichens and mosses as bioindicators. Correlations between air quality and species presence, abundance, and absence have been developed from fumigation studies and observations of distribution with known ambient concentrations of pollutants (Minnesota Environmental Quality Board 1984). The National Park Service is sponsoring fumigation studies of lichens in several national parks and conducting lichen bioindicator surveys in both parks and monuments (Hale 1984; Bennett 1985b).

The reactions of lichens to toxic materials include changes in color, growth reduction, membrane leachage, and mortality. One particular response to air pollutant exposure is a weakening of the cell membrane and subsequent loss of vital electrolytes. This physiological alteration can be used to establish relationships between pollutants and lichen species. A scale of responses can be developed by testing different species' electrical conductivity after exposure to varying pollution regimes. This technique is currently being evaluated in a lichen monitoring system in Zion National Park and the Navajo National Monument in a project jointly sponsored by the National Park Service and the Bureau of Land Management. Lichen biomonitoring has also been proposed for the Bridger Wilderness in Wyoming (Hale 1984) and is currently being conducted for sulfur at Isle Royale, Theodore Roosevelt, Everglades, Shenandoah, and Great Smoky Mountains National Parks (Bennett 1985b).

Using animals as ecosystem indicators of air pollution effects has been proposed (Newman 1975; Newman and others 1981) and has considerable supporting evidence (Grodzinski and Yorks 1981; Newman and Schreiber 1984). Animal species and populations can act as indicators of biotic and abiotic responses of aquatic and terrestrial ecosystems to air pollution. The responses of animals to air pollution have been indicative of altered community energetics and structure, ecosystem life history, chemical cycling, ecosystem genetics, and homeostasis. Animals as biological receptors of air pollutants show not only direct effects at consumer levels but also indicate indirect effects at producer and decomposer levels. For example, in Europe the house martin, an insectivorous bird, has been found to be a very good indicator of both point source and

regional air pollution (Newman and others 1985). Animals are excellent bioaccumulators of certain heavy metals. Certain tissues of birds (feathers) and mammals (hair, antlers) concentrate these metals and can be easily collected and analyzed (Newman 1975; Jenkins 1980).

A third type of biomonitoring approach is the use of large ecosystems or landscapes as biosphere reserves. The United Nations Conference on the Human Environment in Stockholm in 1972 recommended establishment of this type of monitoring, research, evaluation, and information exchange. This program has become known as the Global Environmental Monitoring System (GEMS). As a part of GEMS, biosphere reserves were established. The biosphere reserves are seen as areas where background data on pollutant levels can be obtained, and they serve as early warning sites for monitoring global pollution trends as well as other environmental uses (Wiersma and others 1978). Presently there are 243 biosphere reserves in 65 countries around the world. This biosphere reserve program is coordinated by the Man and Biosphere (MAB) of UNESCO (Anonymous 1985). Wiersma and colleagues (Wiersma and others 1978; Wiersma and Brown 1980; Wiersma 1985) discuss monitoring considerations and some results in determining background concentrations of trace metals in several proposed U.S. biosphere reserves, including Yellowstone, Sequoia-Kings Canyon, Olympic, and Great Smoky Mountains National Parks. Presently a biosphere reserve program is being monitored in Olympic National Park in Washington. Trace element monitoring, using filters, impactors, and teflon plates, is being conducted at several locations in the park (Davidson and others 1985). Six ecosystem parameters are also being measured: moss and lichen productivity, leaf litter fall, litter decay rates, nutrient flux in the soil, and needle population structure (Franklin 1985).

ECOLOGICAL EFFECTS OF AIR QUALITY CONDITIONS

Reported Effects on Ecosystems

From the perspective of wilderness integrity, the effects of air pollution on the ecosystem are of utmost importance. Although much attention has been given to the effects of air pollution on ecosystem components such as single species vegetation studies, past and current effects on whole ecosystems are recognized (Guderian 1977; Miller 1980; National Academy of Science 1981; Peterson and Adler 1982; Newman and Schreiber 1984). Ecosystem effects have been reported from point sources (Carlson and Dewey 1971; Lauenroth and Preston 1984; Nriagu 1984) as well as regional sources (U.S. EPA 1983). Much of the reported information about the effects of air pollution on ecosystems involves studies on forest ecosystems, which table 3 summarizes (Smith 1981; Grodzinski and others 1984; McLaughlin 1985). The quality and quantity of the information depends on the air contaminant (tables 4 and 5). Much less information is available on ecosystem effects on alpine-subalpine, grassland, chaparral, and desert ecosystems (Newman and Schreiber 1984).

Based on the information available, scientists have attempted to characterize the responses of ecosystems to air pollution (Woodwell 1970; Auerbach 1981; Ecological Society of America 1981; Smith 1981; Suter 1981). The proposed responses can be divided into two groups of hypotheses:

1. Air pollution effects can be characterized as causing a reversal of ecosystem successional processes, or
2. Air pollution effects can be characterized as a series of stages of stress to the ecosystem.

Table 3.—Summary of major air pollutant impacts of forest ecosystems in the United States (from Smith 1981)

Region	Forest type	Air pollution impact
Eastern U.S.	Boreal forest	Primary impact from acid deposition, also heavy metal input
	Northern hardwood forest	Sulfur pollution and heavy metal particulates, in southern and western portions photochemical oxidants increasing problem
	Central forest (oak and hickory)	Sulfate and acid precipitation along with trace metals
	Southern forest (oak-pine and longleaf-loblolly-slash)	Least impacted of the forests by sulfur and trace metals
	Tropical forest	Certain areas affected by oxidants and particulates
Western U.S.	Western montane forest	Point source SO_2, F, and trace metal impacts; oxidants in California
	Subalpine forest	Minimal impacts
	California woodlands	Oxidants and particulates
	Southwestern woodlands	Minimal SO_2 and particulate loading

Table 4.—Relative strength of evidence (quantity or quality)[1] available to support forest ecosystems interaction with regional[2] air pollutants (from Smith 1985)

	Air contaminants			
Ecosystem process and component perturbation	**Oxidants**	**Trace metals**	**Acid deposition**	**Total**
I. Nutrient Cycling				
1. Increase nutrient availability				
a. Increase input (fertilization)	0	1	2	3
b. Increase soil weathering	0	0	1	1
2. Decrease nutrient availability				
a. Reduce litter decomposition	0	4	1	5
b. Increase soil acidification	0	0	2	2
c. Increase soil (cation) leaching	0	0	2	2
d. Decrease microbial symbiosis	0	3	1	4
II. Primary Producers (trees)				
1. Reproductive physiology				
a. Reduce flowering	1	1	0	2
b. Reduce pollen production, metabolism	2	1	1	4
c. Reduce cone, seed set	2	0	0	2
d. Reduce seedling survival	3	3	1	7
2. Foliar physiology				
a. Reduce photosynthesis	4	1	0	5
b. Increase (cation) leaching	0	0	2	2
c. Increase necrosis	4	2	0	6
3. Root physiology				
a. Decrease water, nutrient uptake	0	1	1	2
b. Increase necrosis	0	1	2	3
4. Reduce tree growth	4	1	1	6
III. Consumers				
1. Arthropod pest activity				
a. Increase	4	0	0	4
b. Decrease	0	0	0	0
2. Microbial pathogen activity				
a. Decrease	1	2	0	3
3. Other pest activity (viruses, bacteria, nematodes, mistletoes, weeds)				
a. Increase	0	0	0	0
b. Decrease	0	0	0	0
4. Wildlife (bird, mammal) activity				
a. Reduce food	2	0	0	2
b. Reduce habitat	2	0	0	2
c. Increase morbidity or mortality	0	2	0	2
IV. Ecosystem Succession-Species Composition (cause alteration)	4	1	0	5
V. Ecosystem Productivity (increase or decrease biomass accumulation)	4	0	0	4
Total	41	25	18	84

[1]Evidence scale:
0 = extremely limited evidence or hypotheses only
1 = slight evidence
2 = more evidence
3 = greater evidence
4 = considerable evidence including field evidence.

[2]Exclusive of local air pollution effects within several kilometers of point sources.

Table 5.—Classes of interaction of air pollution and temperate forest ecosystems (modified from Smith 1981)

Class of interaction	Forest soil and vegetation: activity and response	Ecosystem consequence and impact
Class I	1. Forest soils and vegetation particulate and gaseous contaminants to the atmosphere	1. Atmospheric burden of contaminants from anthropogenic sources supplemented by forest additions—scale may be local, regional, or global
	2. Forest soils and vegetation remove particulate and gaseous contaminants from the atmosphere	2. Air contaminants transferred from the atmosphere to the biosphere, forest ecosystems supplement natural removal mechanisms
	3. No or minimal alteration of structure or metabolism forest soils or vegetation	3. No adverse ecosystem change evident
Class II	1. Forest tree reproduction, alteration, or inhibition	1. Altered species composition
	2. Forest nutrient cycling, alteration a. Reduced litter decomposition b. Increased plant leaching, soil leaching, and soil weathering c. Disturbance of microbial symbloses	2. Reduced growth, less biomass
	3. Forest metabolism, alteration a. Decreased photosynthesis b. Increased respiration	3. Reduced growth, less biomass
	4. Forest stress, alteration a. Phytophagous insects, increased or decreased activity	4. Altered ecosystem stress; increased or decreased insect infestations
	b. Microbial pathogens, increased or decreased activity	Increased or decreased disease epidemics
	c. Foliar damage increased by direct air pollution influence	Reduced growth, less biomass, altered species composition
Class III	1. Severe morbidity, excessive foliar damage	1. Dramatic change in species composition, reduced biomass, increased erodibility, nutrient attrition, altered microclimate and hydrology
	2. Mortality	2. Forest simplification or destruction

Woodwell (1970) discussed experiments at Brookhaven National Laboratory in New York on the effects of ionizing radiation on the structure and function of forest ecosystems. He proposed the theory that air pollution causes the same pattern of destruction of an ecosystem as does radiation. In essence, what he showed was that with constant bombardment by radiation there was a reversal of the process of ecosystem development with a regression to early developmental stages. The degree of reversal depended upon the amount and duration of exposure to the pollutant. Initially, growth was retarded in trees, especially conifers, with widespread crown killing. Eventually, all the trees died, including the broadleaf trees, followed by the shrubs, herbs, and grasses. There were distinct zones radiating out from the pollution source that reflected the degree of pollution exposure. These zones were also similar to the various stages in development of the exposed oak-pine forest.

The general conclusions drawn from Woodwell's study regarding the effects of pollution on ecosystems are:

1. There is a common pattern of destructive change in terrestrial ecosystems.

2. These changes are similar to those found along natural gradients of increasingly severe conditions. In particular, community structure dominated by trees is reduced to one dominated by shrubs. With more severe conditions there is a reduction from shrubs to low-growing plants, these plants being recognized as pioneer or generalist types. Finally, with increasing severity there is total removal of vegetation.

3. The change in structure is toward simplification or a decrease in spatial heterogeneity.

4. Species richness (both animals and plants) is reduced.

5. The ratio of gross production to community respiration exceeds one.

6. Fewer inorganic nutrients are tied up in the biota and more are lost from the system because of pollution.

7. There is an increased effect of the physical environment on the biotic community.

Two notable examples supporting this theory of air pollution damage to ecosystems are found in Tennessee and Canada. The first case is in an area of southeastern Tennessee called Copperhill (Haywood 1905, 1910; Hursh 1948). It is an area characterized by an oak-pine forest.

Mining for copper started in the 1850's, but the ore was not processed in the area until open hearth smelting began around 1890. The major air pollutant was SO_2, with the greatest production occurring between 1890 and 1895. By 1910 a typical pattern of a destroyed ecosystem developed and still persists today. In 1948, the area was characterized by a bare zone 10.5 mi^2 in size. The area is still increasing in size due to severe erosion. Surrounding the bare zone is a belt of grassland 1 to 2 miles wide comprising 17,000 acres. Erosion gullies from the bare zone constantly undercut the grassland. Surrounding the grassland zone is a mixed zone of grass, shrubs, and trees comprising some 30,000 acres. Those trees present are partially damaged. Beyond this zone is the natural undisturbed forest. The interior zones showed the characteristics of early succession both in terms of plant structure and ecological features. The first plants lost were white pines, then the hardwood trees, shrubs, and finally the grasses.

The second example of similar ecological change is from Wawa, ON, Canada, in a forested area surrounding an iron smelter (Gordon and Gorham 1963; Gorham 1970). The damage at Copperhill was circular. At Wawa the pattern of damage is elongate and conforms to the local wind patterns. Structural damage to the plants is seen 20 miles from the smelter. It is considered severe within 11 miles and very severe within 5 miles of the smelter. The plant species richness decreases from 20 to 40 species per square yard within 10 miles of the smelter to 0 to 1 species per square yard within 2 miles of the smelter. Again, the same pattern of change is present. The most sensitive species, the conifers, disappear first. As a matter of fact, no white pine seedlings were found within 30 miles of the smelter. The categories of damage reflect the pattern of successional reversal:

Moderate—tip killing and crown thinning, extensive in overstory; little damage to understory.

Considerable—overstory almost completely killed, a few white birch and white spruce alive but dying; understory dense but with tip killing.

Very severe—ground vegetation nearly all gone, a little *Polygonum* remaining; erosion evident.

The quality of the waters had also changed drastically. The pH of the lake water 30 miles from the smelter was 6 to 7 but had been reduced to 3 within 5 miles of the plant. Also, the sulfate content of the waters had greatly increased. An inorganic nutrient loss from the system was demonstrated by a significant increase in calcium in the surrounding lake waters.

Air pollution has also been viewed as a stress factor to ecosystems (Auerbach 1981; Smith 1981; Ulrich 1983). Depending upon the amount and severity of air pollution exposure, an ecosystem has various tolerance levels or thresholds. The characteristics of the ecosystem at these various tolerance levels are different. Smith (1981) has applied this concept in describing the responses of forest to air pollution. He divides the interaction of air pollutants and forest ecosystems into three classes (table 5). Under low dose conditions (Class I relationships), the vegetation and soils act as important sinks for air pollutants. In Class I relationships the impact of air emissions may be undetectable or may actually stimulate growth. At intermediate dose levels (Class II relationships), individual tree species or individual members of a given species may be subtly and adversely affected by nutrient stress, impaired metabolism, predisposition to stress from insects or pathogens, or direct disease inductions, all related to the presence of air pollution. Reduced productivity or biomass and alterations in species composition or community structure may also be observed. At high exposure (Class III relationships), acute morbidity or mortality may be observed in specific tree species. Gross simplification of the ecosystem; impaired energy flow and biogeochemical cycling; and changes in hydrology, erosion, and microclimatic alteration, as well as impacts to associated ecosystems, may occur.

Ulrich (1983) has applied the stress concept to the effects of air pollution on soil ecosystems in Europe. His theory is based on the dynamics of the ion cycle within ecosystems. In a steady state, ion uptake and mineralization balance each other. Because ion uptake and mineralization do not always occur at the same place and at the same rate, this buffering capacity (H^+/OH^- ions) determines the resiliency of the ecosystem. Air pollution can destabilize the balanced ion cycle. Ulrich identifies two stability phases: stable with high resilience and stable with low resilience. Several destabilization phases are identified: humus disintegration, buildup of the decomposer refuge, and podzolization. He concludes that all forest ecosystems in central Europe have transferred to one of the destabilization phases.

The U.S. Fish and Wildlife Service has published a series of reports summarizing the effects of air pollution, including acid rain, on fish, wildlife, and their habitats (Air Pollution and Acid Rain, FWS/OBS 80/40 series; for example, Peterson and Adler 1982). These reports are divided into reviews of major habitat types including forest, grasslands, deserts and steppes, arctic tundra and alpine meadows, rivers and streams, lakes, and critical habitats for threatened and endangered species. These reviews point out the diversity of responses by the various ecosystem types. In coastal sage-scrub ecosystems, for example, chronic exposure to photochemical oxidants is reported to cause a decrease in total foliar cover, a decreased number of plant species, and an increased number of dominant species. Effects on plant species composition are reported in oak-grassland and aspen-conifer ecosystems. Particulate pollutants are reported not only to affect species composition but also to affect other ecosystem characteristics causing changes in soil microbial activity, nutrient cycling, and the integrity of food chains in forest ecosystems. Aquatic ecosystems also have been impacted by decreased decomposition and nutrient cycling, altered primary and secondary productivity, and altered trophic levels and competitive relationships. Direct effects to fish and wildlife ranging from biomagnification to increased morbidity and mortality have been reported. Acidifying pollutants have been identified as causing similar effects to both forest and lake ecosystems. Gorham and others (1984) have recently suggested that peatland ecosystems are also vulnerable to atmospheric deposition.

An objective of many of the whole ecosystem studies is to develop a model either to describe or predict ecosystem effects (Miller and Elderman 1977; Tetra Tech, Inc. 1984). Shugart and others (1980) and Kercher and others (1981)

discussed the utility of various models for evaluating stress to forest ecosystems from air pollution. Other examples of available models include a forest succession model (SILVA) for the mixed conifer forest of the Sierra Nevada of California that simulates the effects of SO_2 and fire on forest dynamics (Kercher and Axelrod 1984). Klein (1984) has developed a model to evaluate the effects of acid rain on biomass accumulation, litter, and nutrient pools, and Luxmoore (1980) has created a model for deciduous forest that links water, carbon, and chemical dynamics in a soil-plant-litter system. A major shortcoming of these models to date is that they have little application in the regulatory arena. They are not developed to predict effects at various air quality increments over a baseline condition or effects over short periods, for example 10 years.

Much effort has also been devoted to modeling the effects of acid deposition on surface water systems. A variety of models exist (for instance, Henriksen's predictor nomograph, the Almer-Dicksson relationship, and the Thompson cation denudation rate model), but this field of modeling is still considered developmental in its application to North America (Galloway and others 1984). These models are predictive and useful in determining the effects of additional acidification on soil and aquatic systems.

Reported Effects on Ecosystem Components

Research has traditionally focused on species or populations and only recently on ecosystem level studies (Sheehan and others 1984). Therefore, a major share of the present information on air quality-related values deals with ecosystem components. Drawing on these studies has resulted in a better understanding of which parts of the ecosystem structure and function are most sensitive to air quality degradation and which components may provide the most qualitative and quantitative measures of change.

Effects on Soils.—There is a close relationship between vegetation and soils, and much of the literature on the effects of air pollution discusses both together (Little and Martin 1972; Freedman and Hutchinson 1980). More singular attention has been given to soils in regard to the effects of air pollution on nutrient cycling (Johnson and others 1984) and plant productivity (Jones and others 1979). A number of reviews have summarized known or suspected effects to soils by reviewing both soil and soil-vegetation effects literature (Ulrich and Pankrath 1983; McFee and others 1984).

Soils are receptors of air pollutants. They can act as sinks and accumulate pollutants, or they can alter the chemical nature or reactivity of pollutants. Soils can act as pathways of transport for pollutants to other ecosystem components such as vegetation or animals or to other ecosystems such as lakes and streams (fig. 1). A recent review concludes that natural soil processes can contribute to an increase in H^+ ion concentration in some forest watershed surface waters (Lefohn and Klock 1985). Air pollutants can enter soil directly through deposition (wet or dry) or indirectly through leaching or washing of pollutants from vegetation and by decomposition of contaminated vegetation. Most studies on the effects of air pollutants have involved forest soils (Ulrich and Pankrath 1983; McFee and others 1984).

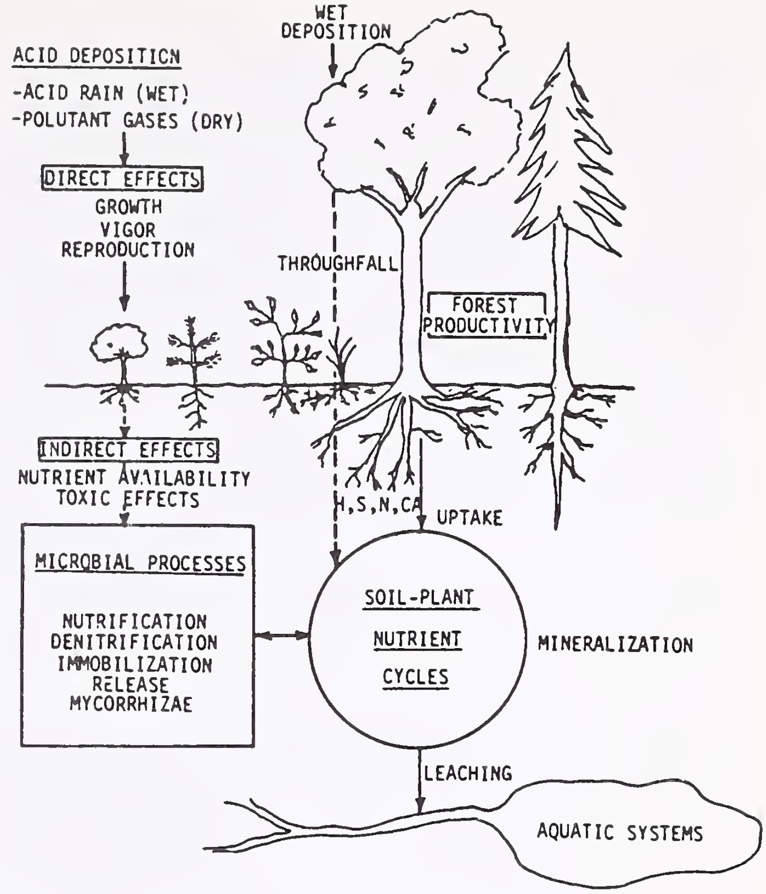

Figure 1.—Key components and processes to be considered in evaluating effects of acidic deposition on forested ecosystems (from Altshuller and Linthurst 1984).

Generalizations about the effects of air pollution on soils are dependent upon the type of soils and the particular pollutant (Cowling and Linthurst 1981). Some soils, such as clays and peats, have the capacity to absorb certain amounts of elements, thus mitigating their effects. In other soils, such as sands, the elements are more available for uptake and transport. Trace metal depostion on soils can have long-term, adverse effects as found at Copperhill, TN, and Sudbury, ON, Canada. Enrichment of soils and zones of concentration of SO_4, NO_3, trace metals, and other pollutants are often observed in soils downwind of point sources (Hutchinson and Whitby 1974; Hogan and Wotton 1984).

The effects of sulfur and other acidic deposition on soils are well summarized (Ulrich and Pankrath 1983; McFee and others 1984). Acid deposition may cause acidification of soils and associated ecosystems or contribute to natural acidification rates. Soil acidification is affected by and controlled by underlying bedrock, waterflow characteristics, and type of plant community. In areas exposed to acid deposition most soils that are easily acidified are already acid. Other soils that are likely to become acidified are limited. Agricultural soils that are amended do not appear to be affected by acid deposition. Assessing the effects of acid deposition on forest nutrient status involves quantifying the inputs and changes in availability of sulfur, nitrogen, and cations on specific sites as well as effects on

microorganisms. The most likely damage to forest productivity may result from aluminum toxicity.

Acid deposition has greatly increased the rate of soil acidification in Europe, especially central Europe. Soil acidification can occur directly from dry or wet deposition or indirectly from conversion (oxidation) of SO_2 to SO_4 in vegetation or particulates washed from vegetation.

A number of effects have been observed in soils including:

- less exchange base cations,
- slower decomposition rates,
- reduced buffering capacity,
- leaching of nutrient cations,
- formation of aluminum ions and their entering into solution,
- decreased penetration of roots to lower soil horizons,
- decreased abundance and diversity of soil organisms with depth, and
- decreased plant productivity due to reduced nutrient availability.

In nutrient-poor soils the addition of sulfur and nitrogen has been found to have a positive effect, if any, on plant productivity. Nitrogen-limited soils are common; therefore, acid inputs are generally felt to be beneficial. Because of the much more limited sulfur-deficient soils, the beneficial effects of sulfuric acid are minimal. The increased mobility of aluminum in naturally acid soils is the most significant effect of acid deposition on soils because this affects processes in both the terrestrial and aquatic ecosystems (McFee and others 1984).

Effects on Vegetation.—Effects of air pollution on vegetation have been the subject of both historical and present-day investigations (Mudd and Kozlowski 1975; Heck and Brandt 1977; Lefohn and Ormrod 1984). The earliest vegetation effects were related to sulfur dioxide from point sources. A number of cases of severe damage to ecological systems from a variety of pollutants have been reported (table 6). More recently, attention has been

Table 6.—Examples of severe ecological damage in North America from air pollution (modified from Smith 1981)

Location	Source (pollutant)	Severely injured or killed species	
Redding, CA	Smelter (SO_2, metals)	Pine, oak	*Pinus* spp., *Quercus* spp.
Anaconda, MT	Smelter (SO_2F)	Douglas-fir, lodgepole pine	*Pseudotsuga menziesii*, *Pinus contorta*
Missoula, MT	Pulp mill (SO_2) (SO_2)	Ponderosa pine, Douglas-fir	*Pinus ponderosa*, *Pseudotsuga menziesii*
Superior, AZ	Smelter (SO_2, metals)	Paloverde	*Cercidium* spp.
Jackson, MS	Nuclear electric generating facility tower (SO_4^{2-})	Southern red oak, eastern white pine, sassafras, white ash	*Quercus falcata*, *Pinus strobus*, *Sassafras albidum*, *Fraxinus americana*
Colstrip, MT	Electric generating complex (SO_2)	Ponderosa pine	*Pinus ponderosa*
Copper Basin, TN	Smelter (SO_2, metals)	Pine, oak, hickory	*Pinus* spp., *Quercus* spp., *Carya* spp.
Columbia Falls, MT	Smelter (F^-)	Ponderosa pine, lodgepole pine	*Pinus ponderosa*, *Pinus contorta*
Trail, BC, Canada	Smelter (SO_2)	Ponderosa pine, Douglas-fir, western larch, lodgepole pine	*Pinus ponderosa*, *Pseudotsuga menziesii*, *Larix occidentalis*, *Pinus contorta*
Anyox, BC, Canada	Smelter (SO_2)	Western redcedar, western hemlock, Pacific silver fir, Sitka spruce	*Thuja plicata*, *Tsuga heterophylla*, *Abies amabilis*, *Picea sitchensis*
Yellowknife, NT, Canada	Smelter (SO_2, As)	Black spruce, white spruce, paper birch, poplar, willow	*Picea mariana*, *Picea glauca*, *Betula papyrifera*, *Populus* spp., *Salix* spp.
Sudbury, ON, Canada	Smelter (SO_2, metals)	Pine	*Pinus* spp.
Wawa, ON, Canada	Smelter (SO_2)	Black spruce, white spruce, fir, pine	*Picea mariana*, *Picea glauca*, *Abies* spp., *Pinus* spp.

given to the effects of acid precipitation on forest and other vegetation types (Johnson and others 1984; Postel 1984). The eastern half of the United States is a geographical area of major concern for the effects of air pollution on forest productivity (McLaughlin 1985). The forests of the area have been identified as being stressed by ozone, SO_2, and acid rain (fig. 2). Comparable concern exists in coastal California and southern California, which have already been impacted by photochemical oxidants (Miller and Elderman 1977).

Armentano and Loucks (1983), evaluating air pollution threats to national parks of the Great Lakes region, concluded that a number of parks in southern parts of the region (for example, Indiana Dunes National Lakeshore) have pollutant concentrations above the thresholds known to cause ecological effects in plants. Parks in the Great Lakes region located at great distance from primary emission sources are considered to be actually or potentially threatened by air pollution (table 7). The National Park Service has recently developed an air pollution-ecological sensitivity rating for its parks and a number of parks (approximately 20) have been found to exhibit the criteria for ecological damage (Bennett and others, this proceedings).

The effects of air pollutants on vegetation have primarily been discussed as effects to individual plants. These effects have been grouped as visible or subtle effects (Heck and Brandt 1977); acute, chronic, and hidden injury (Mudd and Kozlowski 1975); damage causing economic loss; and acute and chronic injury related to foliar and other effects (Applied Science Associates, Inc. 1978). Until recently most attention has been given to investigating the effects of a single pollutant, although in field conditions combinations or mixtures of pollutants are often the cause of damage (Lefohn and Ormrod 1984). Pollutants can affect every stage of plant development and reproduction. Besides effects on photosynthesis and respiration, pollen viability, flower and fruit abscission and set, fruit and seed development, viability, and survival can be affected (Treshow 1984).

Acute injury refers to cell death and may involve a part of a leaf or a whole leaf. Plasmolysis of the cells occurs with a subsequent collapse of the tissue. Adjacent segments of the leaf may be affected. The affected areas dry out, giving a necrotic pattern which tends to be characteristic of a given pollutant. Acute symptoms are associated with short-term exposures (hours) to varying concentrations and conditions. These symptoms usually appear within 24 hours.

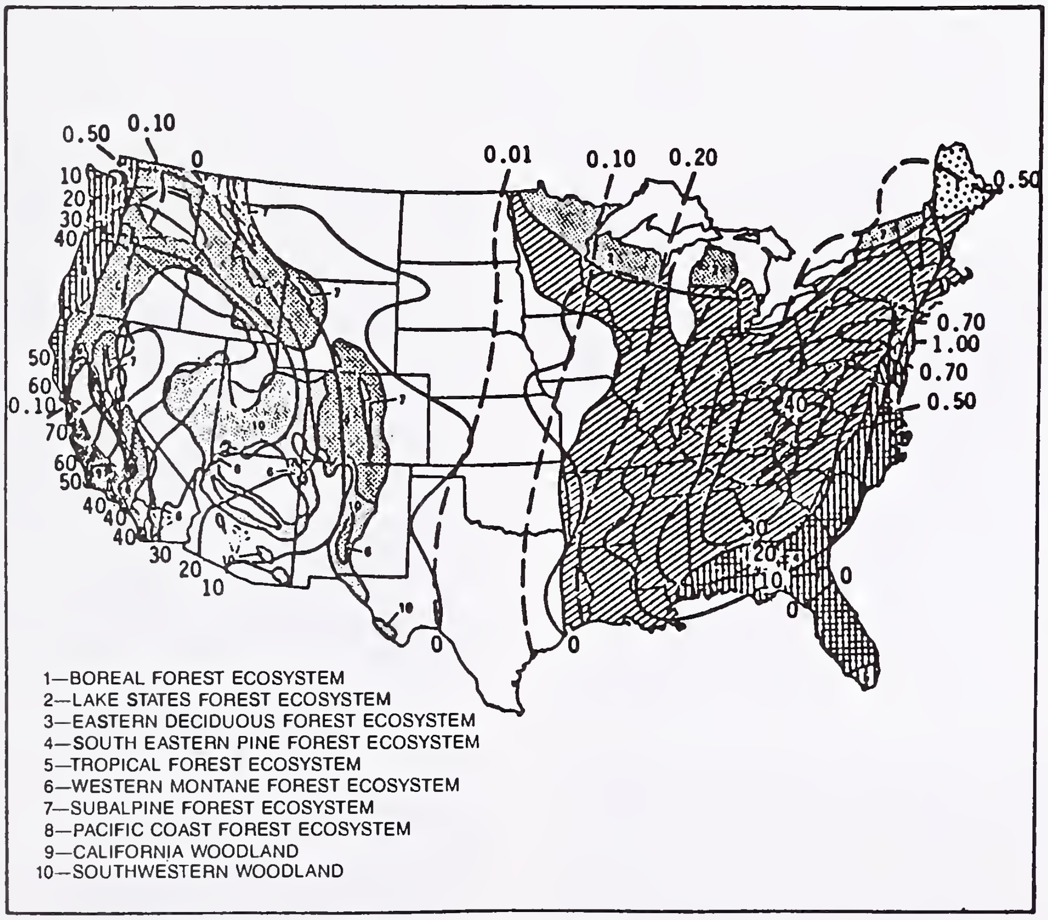

Figure 2.—Distribution of frequency isopleths for total number of forecast days with high meteorological potential for air pollution over a 5-year period. Isopleths are shown in relation to major forest types of the United States and in relation to mean annual hydrogen ion (kg/ha/yr) deposition in precipitation (from Altshuller and Linthurst 1984).

Table 7.—Actual and potential air pollution-induced threats to Great Lakes national parks and other Federal lands (modified from Armentano and Loucks 1983)

Site	Major natural resources	Sources of threat			
		SO_2 vegetation effects	O_3 vegetation effects	Visibility reduction	Acid deposition aquatic effects
1. Voyageurs National Park	Forest, lakes, stream		+	+	+
2. Grand Portage National Monument	Forest, streams, vistas		+	+	+
3. Isle Royale National Park	Forests, wildlife, streams, vistas		+	+	+
4. Apostle Isle National Lakeshore	Forests, shorelines, vistas	+		+	+
5. St. Croix National Scenic Riverway	Forests, streams, gorges, wildlife		+	+	+
6. Pictured Rocks National Lakeshore	Forests, beach outcrops, vistas		+	+	+
7. Sleeping Bear Dunes National Lakeshore	Beaches, vegetation, vistas		+	+ +	
8. Indiana Dunes National Lakeshore	Beaches, vegetation, wildlife	+ +	+ +	+ +	
9. Perry's Victory National Monument	Historical values, vistas			+ +	
10. Cuyahoga Valley National Recreational Area	Vegetation, topography, vistas	+ +	+ +	+ +	

+ = significant potential for future effects in the next two decades unless major reductions in pollutant loadings occur.

+ + = resources alterations are probably occurring now for specific pollutants indicated.

Chronic injury may be mild or severe and may also lead to cell death when cellular activity is disrupted. Chlorosis, the loss or reduction of green plant pigment, and chlorophyll or other color pigment changes may result. A second chronic effect is reduction in growth. This may be observed with or without visible foliar injury (Mudd and Kozlowski 1975). Chronic injury symptoms are not generally characteristic of a given pollutant and are more likely associated with long-term or intermittent exposures to various concentrations of pollutants (Heck and Brandt 1977). If representative of other pollutants, long-term, low-level exposure may cause growth reduction without manifesting visible injury.

Leaves are the primary focus for describing injury from air pollution. This is not to say that other plant organs, such as flowers, fruits, seeds, roots, and stems, are not sensitive or do not show injury. In general, these organs are either not directly exposed to air pollutants or their exposure is of shorter duration. Fluoride, for example, is damaging to gladiolus flowers and leaves. Injury to leaves, resulting in growth effects, may be manifested in other organs that may be used to detect effects (Applied Science Associates, Inc. 1978). A common example of this is tree ring analysis of stems to infer historical air pollution effects (fig. 3).

Besides the type of pollutant, its concentration, and duration of exposure, many environmental factors will influence a plant's response to air pollution. These include climatic factors—light, temperature, relative humidity, and soil nutrition. These factors and the seasons associated with growth can increase the sensitivity of plants to air pollution (Mudd and Kozlowski 1975).

Besides direct injury, other aspects of air pollution effects on vegetation need to be considered. Plants can accumulate pollutants and such accumulations, in addition to being directly injurious, can be harmful to animals that eat such tissues for food. Such a problem has been well documented for hydrogen fluoride and certain airborne particulates such as lead, cadmium, and arsenic (Carlson and Dewey 1971; Newman 1980; Newman and Schreiber 1985). Plants can accumulate these pollutants in their tissues or on their surfaces.

As mentioned in the beginning of this section, emission sources often release multiple pollutants that affect vegetation (Runeckles 1984). Only recently has this condition been given national attention (Lefohn and Ormrod 1984). Because of existing Federal standards, research priority is currently focused on the co-occurrence effects of ozone, nitrogen dioxide, and sulfur dioxide mixtures in air. However, any combination of pollutants, such as fluoride and

Figure 3.—Calculated average cross-section of two 30-year-old ponderosa pines at breast height grown in polluted air (left) and in nonpolluted air (right) based on radial growth samples from 1941 to 1971 and 1910 to 1940 (from Miller and Elderman 1977).

sulfur dioxide, may occur. There is the possibility that, because of synergistic effects, observed visible injury will total more than the sum of visible injury exhibited by each pollutant alone. Either an antagonistic effect or no effect is also possible. The threshold of injury is important. When pollutant concentrations are below or at their individual thresholds for visible injury, synergistic effects are often observed. Antagonistic interactions may be observed at relatively high concentrations. Insufficient experimental studies have been conducted, however, to develop diagnostic symptoms as have been described for single pollutant effects. In some mixtures, injury symptoms of one of the pollutants may be apparent while with other mixtures the symptoms may differ from those of any single pollutant in the mixture. From a wilderness protection point of view, the consideration of co-occurrence of air pollutants from a combination of nearby emission sources and from regionally derived pollutants may be critical.

Besides the direct injury to vegetation, air pollutants can create conditions which enhance other stresses on vegetation. Pollutant-plant pathogen interactions have been well documented (Heagle 1973), as have interactions between air pollutants and plant parasites. For example, in southern California considerable damage to ponderosa pine in the San Bernardino National Forest was attributed to the interaction of photochemical oxidants and western pine beetle (*Dendroctonus brevicomis*) populations (Miller and Elderman 1977). Such conditions are likely to occur in wildernesses where indigenous insects may be aided by air pollution. Air pollutants may either weaken the resistance of plant species to pest infestation, or if significant defoliation occurs because of plant pests, this may allow air pollutants to penetrate farther into the vegetation causing additional injury and further increasing susceptibility to other stresses (fig. 4). Similar interactions are suspected to occur with acid deposition (fig. 5).

The Critical Assessment Review Papers (Johnson and others 1984) draw a number of conclusions regarding the effects of acid and gaseous deposition on vegetation:

1. Ozone is the most important gaseous pollutant affecting plant life distant from industrial and urban precursor sources.
2. Direct effects, including foliar injury and reduction in growth and yield, have been recorded in forest ecosystems.
3. The effect of acid deposition on nutrient cycling and subsequent effects to plant growth and yield are important if the rate of leaching exceeds the rate of nutrient uptake.
4. At present, no direct evidence exists that acid deposition limits forest growth in either North America or Europe; however, evidence from annual rings indicates that tree growth rates are lower in coniferous forests where the rainfall acidity is high or the annual average pH of precipitation is low (pH <4.3).

The major research needs relating to air quality effects on wilderness vegetation are additional cause-and-effect relationship studies in field conditions. Studies are needed

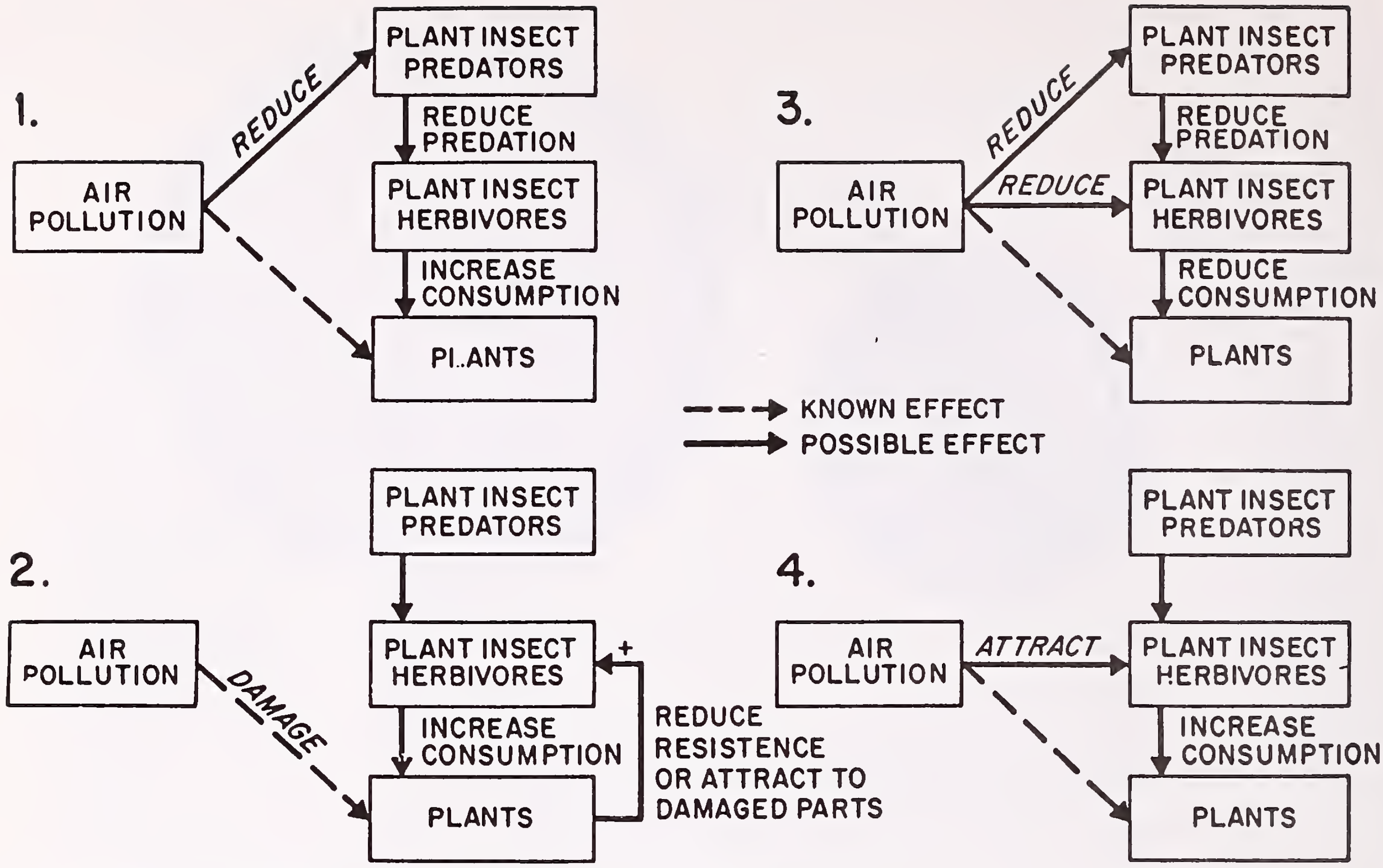

Figure 4.—Four possible mechanisms of air pollution impacts on insect-plant relations (from Newman 1975).

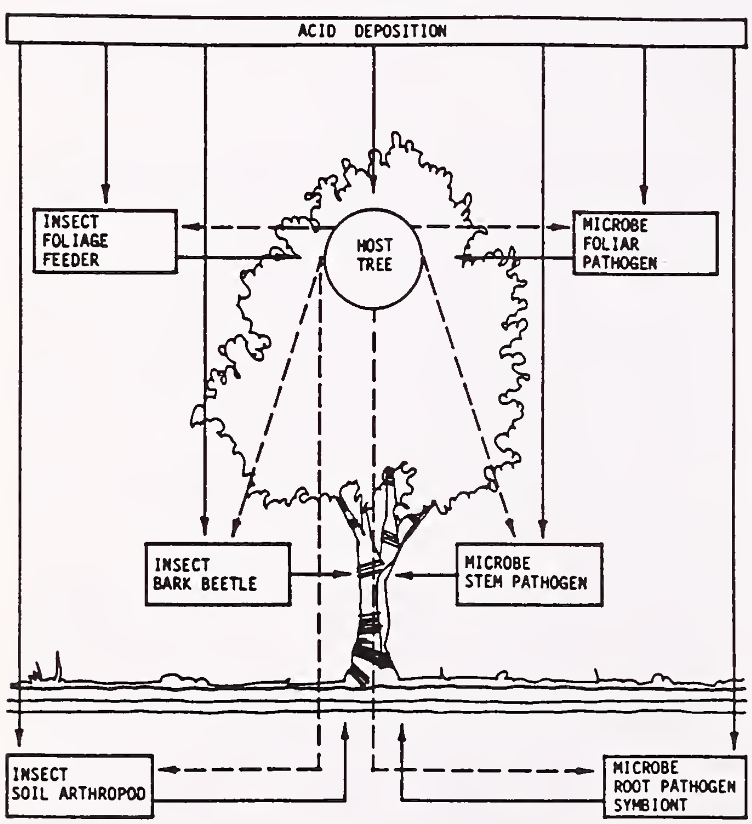

Figure 5.—Acid deposition may influence insects, pathogens, and symbionts associated with forest trees by direct influence (solid arrows) or indirect influence via host alteration (dashed arrows) (from Altshuller and Linthurst 1984).

to show whether observed declines and damage to vegetation at a regional scale are due to air pollution. In addition, the separation of multistress factors and determination of the contribution of air pollution to observed changes in vegetation are also needed (Bennett 1985a).

Effects on Water.—Water is a sink for many pollutants. The sources of these pollutants range from agricultural runoff to industrial waste effluents. Where these multiple sources of contamination exist, pinpointing the contribution of air pollution and correlating the effects on aquatic organisms are difficult. Aquatic ecosystems in close proximity to a major emission source have been shown to be affected (Lefohn and Brocksen 1984; Nriagu 1984). The major atmospheric influences from emission sources are acid deposition and trace metals. These influences can be from direct deposition on the water body or from input through the watershed.

Considerable effort has been devoted to characterizing the sensitivity of aquatic ecosystems to water quality change caused by acid deposition (Hendrey and others 1980; Lippincott and others 1982; Loucks and others 1984; Brakke and others 1985). For rivers and streams, high order (<3) and soft water systems are considered to be the most sensitive. These systems are characterized by cold (<68 °F), shallow waters, with turbulent flow and rubble and gravel substrates. There is usually a high gradient and extensive shade and cover. The waters contain coarse particulate organic matter and have low alkalinity (Potter and

others 1982). Larger rivers and streams at lower elevations or in more developed areas are likely to be less affected because of greater buffering capacity, dilution, and inputs from other anthropogenic sources (Potter and Alder 1982; Haines and Akielaszek 1984).

Lake sensitivity is well studied (Tetra Tech, Inc. 1984). The less the ability of the watershed to neutralize the acid deposition, the more sensitive the lakes are to acidification. Sensitive lakes are those with low total alkalinity, neutral or below neutral pH, low hardness, low conductivity, and generally low productivity.

Geographical areas where acid deposition is recognized as affecting or potentially affecting aquatic systems include New England and the Adirondack region; the Middle Atlantic and Appalachian area plus parts of the Southeast, including Florida; portions of the upper Midwest; and some higher elevation areas of the Rocky Mountains, Pacific Northwest, and California. The current National Surface Water Survey is an attempt to further define these areas of sensitivity and to establish long-term monitoring for trend analysis (Brakke and others 1985). Recent attention has focused particularly on the situation in the West (Lippincott and others 1982; Gibson and others 1983; Roth and others 1985). Because of the number of wildernesses in the West, this potential threat to water quality via atmospheric transport should be carefully monitored. The Environmental Protection Agency has recently summarized what is known or suspected about the effects of acid deposition on aquatic systems (Wilhour 1985). These include:

- Episodic acidification events (storms and snowmelt) may be more important than long-term chronic acidification in some aquatic ecosystems.
- Bedrock, soils, hydrological characteristics, vegetation, land use, and climate can all affect "susceptibility."
- Alkalinity is the best single measure of sensitivity.
- Some regions of the country currently receive elevated concentrations of trace elements in the deposition.

Water quality changes resulting from acid deposition include reduction in pH of the water and the form and availability of metals. The degree of pH reduction is related to the amount of acid material deposited directly into the water body or deposited in the watershed and flowing into the system from surface or ground water flow. The buffering capacity of the terrestrial and aquatic systems moderates the chemical response. The mobilization of aluminum from terrestrial systems is a major factor because its availability and that of other trace elements in water increases with acidic conditions (Potter and others 1982; Altshuller and Linthurst 1984). The effects of these water quality changes on organisms are discussed in the next section.

Effects on Fish and Wildlife.—The impact of airborne pollutants on fish and wildlife resources is usually more difficult to discern than for other ecosystem components. The effects are more likely subtle or indirect, such as contaminated vegetation consumed by terrestrial wildlife or bioaccumulation of metals in the aquatic food chain. Recent reviews have summarized much of this information (Drablos and Tollan 1980; Newman 1980; Haines 1981; Haines and Johnson 1982; Fischer 1983, 1984; Altshuller and Linthurst 1984; Mayer and others 1984; Schreiber and Fischer in press; Schreiber and Villella 1985). Our incomplete understanding of responses and consequences from acute or chronic events of degraded air quality for both terrestrial and aquatic species at the individual or population level is evident when impact assessment is required.

Effects of airborne pollutants on fish and wildlife resources have been recorded for a number of years, but both the frequency and diversity of pollutants and the number of species impacted have increased in recent years (Newman 1975, 1980; Haines 1981; Newman and Schreiber 1985). The effects have been physiological, toxicological, and ecological (Dvorak and Lewis 1978; Fromm 1980; Newman 1980). In both terrestrial and aquatic ecosystems the impacts tend to follow pathways that involve: (a) metal accumulation and toxicity, (b) alterations in nutrient and energy cycling, (c) changes in food resources, and (d) loss or degradation of habitat (Fritz 1980; Clark and Fischer 1981; Baker and others 1984; Schreiber and Fischer in press; Schreiber and Villella 1985).

For aquatic species that depend on the water environment for some part of their life cycle, the effects are often the most direct and perhaps the most dramatic. Air pollutants may interact with the aquatic media either directly (dry and wet deposition) or indirectly after interception and alteration by the terrestrial environment (soils, vegetation). As indicated in the previous section, the result of this interaction may add materials which cause damage to aquatic biota and change ecosystem processes. For example, low-pH precipitation caused by acidifying pollutants can leach aluminum from the soils, creating runoff that contains aluminum levels toxic to aquatic organisms. Acid precipitation causes loss of buffering capacity in low-alkalinity waters, ultimately reducing species diversity and productivity and simplifying the ecosystem (Drablos and Tollan 1980; Haines 1981; NRCC 1981; Swedish Ministry of Agriculture 1982; Baker and others 1984). Food availability and quality can decrease as the trophic dynamics of the aquatic system are changed. Aquatic taxa demonstrate wide ranges of pH tolerance (tables 8 and 9). When acid-sensitive species are reduced or eliminated, the competitive advantage shifts to more acid-tolerant organisms.

Direct impacts of low pH to fish species may include acute mortality, osmoregulatory failure and other physiological stress; predisposition to disease; and reproductive stress, including endocrine imbalances, curtailed spawning, and genetic damage, leading to recruitment failure (Baker and others 1984). The combination of low pH and aluminum that may occur in spring runoff can induce excess mucus secretion in the gills of fish, causing death by asphyxiation. Episodic depressions in pH are particularly threatening to eggs and the early life stages of fish when there is generally lower acid tolerance (NRCC 1981). Mobilization of metals by acid precipitation can also lead to bioaccumulation, affecting fish and other top predators in the aquatic food chain. For example, elevated levels of mercury have been detected in fish from acid lakes (Wiener 1983) although the consequences to the species or its predators, including piscivorous birds and mammals, are unknown.

Table 8.—Median minimum pH tolerances of different aquatic taxa (adapted from Eilers and others 1984)

Taxonomic group	Median pH tolerance
Algae	
Bacillariophycea (diatoms)	6.0
Desmidiaceae (desmids)	5.25
Chlorophyta (green algae)	4.6
Cyanophyta (blue-green algae)	4.5
Euglenophyta (flagellates)	3.1
Insects	
Odonata (dragonflies)	6.4
Trichoptera (caddisflies)	6.3
Ephemeroptera (mayflies)	6.0
Hemiptera (bugs)	6.0
Diptera (true flies)	5.6
Coleoptera (beetles)	5.5
Plecoptera (stoneflies)	5.2
Miscellaneous groups	
Pelecypoda (bivalves)	6.65
Gastropoda (snails)	6.6
Hirudinea (leeches)	6.55
Porifera (sponges)	5.5
Crustacea (crustaceans)	5.2
Teleostei (fish)	4.9
Anura (frogs)	4.1

Table 9.—Approximate pH at which reproductive failure has been observed in fish (compiled from Baker and others 1984; Haines and Johnson 1982)

Species	pH range
Smallmouth bass (*Micropterus dolomieui*)	6.0+ to 5.5
Walleye (*Stizostedion vitreum vitreum*)	
Burbot (*Lota lota*)	
Atlantic salmon (*Salmo salar*)	5.5 to 5.0
Brown trout (*Salmo trutta*)	
Lake trout (*Salvelinus namaycush*)	
Rainbow trout (*Salmo gairdneri*)	
Trout-perch (*Percopsis omiscomaycus*)	
Brook trout (*Salvelinus fontinalis*)	5.0 to 4.7
White sucker (*Catostomus commersoni*)	
Rock bass (*Ambloplites rupestris*)	
Lake herring (*Coregonus artedii*)	4.7 to 4.5
Lake chub (*Couesius plumbeus*)	
Yellow perch (*Perca flavescens*)	

Amphibians and waterfowl are also candidates for impacts from airborne pollutants that enter the aquatic ecosystem. Amphibians are vulnerable because their prime breeding sites are often small, temporary ponds formed from snowmelt and spring rains (Clark and Fischer 1981; Tome and Pough 1982; Pierce 1985). The reported effects on amphibians from pH depressions include:

- embryo deaths and deformities,
- decreased egg masses,
- reduced densities,
- increased percentage of dead or molded egg masses,
- osmoregulatory failure,
- delayed development,
- abnormalities, and
- decreased sperm motility (U.S. EPA 1983).

Although the role of amphibians in nutrient flow and their contribution to the food chain are often overlooked (Pierce 1985), their reduction or loss would be expected to cause major changes in ecosystems structure and function. They may also provide an early indication of pollutant stress (Perley and Fischer 1983; Newman and Schreiber 1984) and thus may be particularly useful for monitoring in wildernesses.

Present information on the effects of air pollutants on waterfowl is inconclusive. It is likely that piscivorous species such as loons (*Gavia* spp.), herons, and mergansers (*Mergus* spp.) will be unable to rear young in areas where acidification has reduced fish populations. Other waterfowl species, such as the mallard (*Anas platyrhynchos*) and common goldeneye (*Bucephala clangula*), may benefit to some degree from the increased availability of aquatic invertebrates resulting from reduced competition in fishless lakes (Eriksson 1984; Baker and others 1984).

For fish-eating birds, such as the osprey (*Pandion haliaetus*), which search for fish while flying or hovering over the water surface, any benefit of increased water transparency in acid lakes is likely offset by the reduction in fish populations (Eriksson 1984, 1985). Birds at the top of the aquatic food chain may also risk greater exposure to heavy metals that are mobilized by the acidic conditions (Nyholm 1981), although the question is still debatable.

Terrestrial wildlife are potentially affected by air pollution through inhalation of airborne gases and particulates, by drinking water or consuming food that has been affected by these pollutants, or indirectly by the influence of these materials on their habitat (Newman 1980; Schreiber and Fischer in press; Schreiber and Villella 1985). A number of incidences demonstrating impacts have been recorded historically (Newman 1980) and in recent years (tables 10 and 11).

Terrestrial species are likely to show bioaccumulation of metals because of their position in the food chain. Some metals, such as mercury, cadmium, and lead, may enter the terrestrial ecosystem directly through atmospheric transport, whereas others, such as aluminum, may enter indirectly through the acidification process. Once mobilized, these trace elements may be incorporated in the vegetation and subsequently ingested by wildlife. This evidence has been summarized (Newman and Schreiber 1985; Schreiber and Fischer in press; Schreiber and Villella 1985), but impacts to populations remain inconclusive for the most part. In wilderness areas the general

Table 10.—Examples of incidents involving the adverse effects of airborne pollutants and birds (modified from Newman 1980; Newman and Schreiber 1985)

Species	Pollutant	Effect
Small birds	Hydrogen sulfide	Death
House martins (*Delichon urbica*), swifts	Particulates	Reduced populations
House sparrows (*Passer domesticus*)	Fluoride	Biological concentrations
House sparrows	Photochemical oxidants	Respiratory lesions
Passerines	Hydrogen sulfide	Death
Sparrow (*Passer* spp.)	Cadmium	Death
Larks	General air pollution	Reduced populations
Sparrowhawks, song thrushes, owl	Cadmium	Food chain magnification
House martins	Sulfur dioxide, particulates, nitrogen oxides, fluoride	Reduced nesting
Ducks	Trace metals	Biological concentration
Owls, songbirds	Hydrogen sulfide	Death
Pigeons	Lead	Biological concentration

Table 11.—Examples of incidents involving the adverse effects of airborne pollutants and mammals (modified from Newman 1980; Newman and Schrieber 1985)

Species	Pollutant	Effect
Fallow deer (*Dama dama*)	Arsenic	Death
Red deer (*Cervus elaphus*) Roe deer (*Capreolus capreolus*) Rabbits (*Oryctolagus cuniculus*)	Arsenic	Death to 60 to 70 percent of individuals
White-tailed deer (*Odocoileus virginianus*)	Fluoride	Fluorosis
Hares (*Lepus europaeus*)	Sulfur dioxide, fly ash	Hypocalcemia and hypoproteinesis
Bighorn sheep (*Ovis canadensis*)	Oxidants	Blindness
Voles, mice, rats, and shrews	Lead, cadmium, copper	Biological concentrations
Small mammals	Oxidants	Reduced populations
Roe deer	Sulfur dioxide, particulates	Reduced antler quality
Wood mice, bank voles	Fluoride	Biological concentrations
Black-tailed deer (*Odocoileus hemionus*)	Fluoride	Browse contamination
Deer mice (*Peromyscus* spp.)	Ozone	Genetic change in sensitivity to ozone
Bats, mice	Hydrogen sulfide	Death
Foxes	Fluoride	Biological concentrations

lack of monitoring and paucity of historic and current baseline data would likely further preclude the detection of this impact.

In cases where the pollutant affects a food resource, the ramifications to both individuals and populations may be significant. For example, populations of insectivorous birds may be affected when their prey is influenced by air pollution (Newman and others 1985). Species with restricted diets, which include some of the threatened or endangered wildlife, are at particular risk in these circumstances.

Case Studies of Ecosystem Research Programs

In the past 15 to 20 years a number of large-scale, comprehensive studies have been conducted in the attempt to determine the influence of individual or combinations of airborne pollutants on various types of ecosystems (tables 12 and 13). Each study has significantly increased our understanding of the interaction of transient gases and particulate matter on terrestrial and aquatic systems. These ecosystem studies have been of several types—studies to assess an already recognized problem (for example, San Bernardino Mountains photochemical oxidant study), studies to assess potential effects of air pollution (for example, Colstrip studies), and studies to develop assessment tools for air pollution effects (for example, integrated lake-watershed acidification studies). Many of the large ecosystem studies are now concerned with acid deposition effects. Although ozone is recognized as an equally serious problem, only one ecosystem-level study on its effects has been undertaken, and funding was unavailable for its completion. These ecosystem-level studies are important for wilderness evaluations because they have demonstrated the multilevel, interactive component effects that air pollution has on natural systems.

The following case studies are representative of these types of projects and their relevance to wilderness research.

Table 12.—Major ecosystem studies on the effects of air emissions in North America (modified from Newman and Schreiber 1984)

Name of study	Ecosystem (location)	Pollutant stress
Experimental Lakes Area (ELA) watershed studies	Lakes in northern coniferous forest (Ontario)	Acid deposition
Turkey Lake Forest watershed study	Lakes in northern deciduous forest (Ontario)	Acid deposition
Dorset watershed studies	Lakes in northern forest (Ontario)	Acid deposition
Montmorency experimental forest study	Northern coniferous forest and associated lakes (Quebec)	Acid deposition
Kejimkujik calibrated catchment program	Northern coniferous forest (Nova Scotia)	Acid deposition
Integrated Lake-Watershed Acidification study (ILWAS)	Lakes in northeastern deciduous forest (New York)	Acid deposition
Kaybob gas plant study	Transition montane boreal forest (Alberta)	SO_2
Coal-fired powerplant project at Colstrip	Northern grassland (Montana)	SO_2 and particulates
San Bernardino mountain study	Mixed coniferous forest (California)	Oxidants
Whitecourt gas plant study	Mixed coniferous forest (Alberta)	SO_2
Hubbard Brook ecosystem project	Northern mixed deciduous coniferous forest (New Hampshire)	Atmospheric deposition including acid and trace elements
Walker Branch watershed study	Mixed deciduous forest (Tennessee)	Atmospheric deposition including acid and trace elements

Table 13.—Preliminary survey list of existing air pollution-ecological field studies for various locations in North America

Location	Pollutant	Organism or ecosystem component	Reference or contact
Everglades NP, FL	SO_2	Lichens	Environmental Sciences and Engineering, Inc., Florida - R. Hart
Everglades NP, FL	SO_2	Bromeliads and orchids	Oberlin College - D. Benzing
Class I area national parks	SO_2 Ozone, wet deposition	Sensitive plant species ranking	Oak Ridge National Laboratory - R. Olson
Cuyahoga Valley NRA, OH	Various air pollutants NO_x, O_3, SO_2	Eastern white pine (*Pinus strobus*)	Ohio State University - J. McClenahin
British Columbia	Ozone	Native fir species	Ministry of Environment - J. Van Barneveld
British Columbia coastal area	Acid deposition	Salmon	Fisheries and Oceans, Canada
Upper Midwest	Acid precipitation	Lakes and associated aquatic resources	USEPA Research Laboratory, Duluth, MN - G. Glass
Voyageurs NP, MN	Acid precipitation	Lakes, water quality	U.S. Geological Survey - G. Payne
Voyageurs NP, MN	Acid precipitation	Northern pike (*Esox lucius*) (spawning)	Voyageurs NP - L. Kallemeyn
Voyageurs NP, MN	Sulfur and other elements	Lichens	University of Minnesota - C. Wetmore
Voyageurs NP, MN	Acid precipitation	Lakes, water quality	University of Western Iowa - W. DeKock
Nine parks	Ozone	Hardwood trees	Michigan Technological University - D. Karnosky
Voyageurs NP, MN	Ozone	Bioindicators—variety of plant species	University of Minnesota - P. Teng
Upper Midwest including Voyageurs NP, MN	Acid precipitation	Lakes, aquatic chemistry	University of Minnesota - P. Brezonik
Shenandoah NP, VA	Lead and sulfur	Lichens	George Mason University - J. Lawrey
Joshua Tree NM, CA	Oxidants	Desert plants	University of California - P. Temple
Western Tennessee	Acid deposition	Forest soil invertebrates and small burrowing animals	Mississippi State University - R. Esher
Coastal California	Ozone and SO_2	Coastal sage scrub vegetation	NASA-Ames Research Center - W. Westman
Glen Canyon NP; Canyonlands NRA, AZ	SO_2	Vegetation	National Park Service - P. Sanchini
Everglades NP, FL	SO_2	Slash pine (*Pinus elliottii*)	National Park Service - J. Bennett
Lostwood NWR, ND	SO_2, particulates	Lichens	Fish and Wildlife Service
Glacier NP, MT	Acid deposition, particulates	Lichens	National Park Service - Glacier NP
Zion NP, UT	SO_2, particulates	Lichens	National Park Service - Sequoia NP
Craters of the Moon W, ID	Acid deposition, particulates	Unspecified biomonitors	National Park Service - Craters of the Moon
Flat Tops W, CO	Various	Lichens	Forest Service - White River National Forest
20 Eastern U.S. parks	Ozone	Common milkweed (*Asclepias* spp.)	National Park Service - Division of Air Quality
Hampton NHS, Gettysburg NMP, VA; Fredricksburg-Spotsylvania NMP, VA; Petersburg NB	Ozone	Black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), wild grape (*Vitis* spp.), sassafras (*Sassafras albidum*), tulip poplar (*Liriodendron tulipifera*), dogwood (*Cornus* spp.), milkweed, witchhazel (*Hamamelis virginiana*), eastern redbud (*Cercis canadensis*), eastern white pine (*Pinus strobus*), Austrian pine (*Pinus nigra*), foliar injury	National Park Service - Division of Air Quality

(con.)

Table 13. (Con.)

Location	Pollutant	Organism or ecosystem component	Reference or contact
Isle Royale NP, MI; Theodore Roosevelt NP, ND; Everglades NP, FL; Shenandoah NP, VA; Great Smoky Mountains NP, TN-NC	Sulfur	Lichens	National Park Service - Division of Air Quality
Shenandoah NP, VA	Lead	Lichens	National Park Service - Division of Air Quality
Great Smoky Mountains NP, TN-NC	Lead	Leaf litter	National Park Service - Division of Air Quality
Big Thicket NP, TX	Sulfur, heavy metals	Spanish moss (*Tillandsia usneoides*)	National Park Service - Division of Air Quality
Mount Rainier NP, WA	Arsenic	Subalpine fir foliage	National Park Service - Division of Air Quality
Great Smoky Mountains NP, TN-NC	Heavy metals	Red spruce (*Picea rubens*)	National Park Service - Division of Air Quality

NP = National Park; NM = National Monument; NRA = National Recreational Area; NHS = National Historical Site; NMP = National Military Park; NB = National Battlefield; NWR = National Wildlife Refuge; W = Wilderness.

Effects of Emissions From a Coal-fired Powerplant on a Northern Prairie Grassland.—

Ecosystem Type/Location/Duration:

A pristine northern plains grassland, with scattered stands of ponderosa pine; Rosebud County in southern Montana; started in 1974 and completed in 1980 (Lauenroth and Preston 1984).

Pollutant Type/Source:

Stack emissions (particularly SO_2) from two 350-megawatt coal-fired generating units; simulation experiments with a zonal air pollution system (ZAPS) for SO_2 stress.

Objectives:

To measure and predict change in a grassland ecosystem as a function of environmental variables including air pollutants.

Methods and Monitoring Techniques:

The approach was to study the field response to pollution stress by the major parts of the trophic structure of the ecosystem, including representative populations of the microorganisms, producers, and consumers. To complement these field investigations, laboratory experiments were conducted to evaluate ecosystem behavior to selected trace metals associated with emissions from coal-fired powerplants. One of the unique features was the development of a controlled zonal air pollution system (ZAPS) for field fumigation experiments. This network of perforated pipes provided exposure regimes of SO_2 that simulated short-term acute and long-term chronic fumigation events.

Major Results and Conclusions:

The Colstrip coal-fired powerplant project in Montana was a first attempt at generating methods to predict the bioenvironmental effects of air pollution before damage was sustained. The supporting field and laboratory process studies were designed to investigate the mechanisms for cause-effect relationships. The project incorporated environmental characterization of the grassland ecosystem prior to construction of the powerplant and subsequent monitoring of the key ecosystem components after operation to detect impacts from the air pollution. Initial predictions of large and obvious impacts from SO_2 exposure did not occur, and emphasis shifted toward determining appropriate indicators of impact.

In this grassland study, grasses and lichens predominated. Previous grazing and annual climate variations excluded grasses as a reliable indicator of stress, but lichen species were sensitive in detecting SO_2 levels. Research demonstrated that the increase in concentration and accumulation of sulfur by vegetation was related to level and duration of exposure, productivity and growing season, soil nutrients, and defoliation treatments. However, only at very high SO_2 treatment (1 to 2 orders of magnitude greater than current PSD standards) were there indications of direct toxic effects.

For the heterotrophs studied, total arthropod populations were not significantly affected, but some soil-water-associated organisms showed declines. Laboratory studies of grasshoppers suggested physiologically marginal individuals were adversely affected by SO_2 exposure. Palatability of exposed leaves was reduced. The pollen-nectar feeding group of arthropods showed a decline, apparently due to their SO_2 sensitivity.

Effects of Photochemical Oxidant Air Pollution on a Mixed Conifer Forest Ecosystem.—

Ecosystem Type/Location/Duration:

A western mixed-conifer mountain ecosystem; the San Bernardino Mountains of southern California; started in 1973 and completed in 1978 (Miller and Elderman 1977; Miller 1983).

Pollutant Types/Source:

Photochemical oxidants from urban sources in Los Angeles basin.

Objectives:

To determine chronic effects of photochemical oxidants on a mixed conifer ecosystem including forecasting ecological effects, evaluating consequences of pollutants in a forest ecosystem on human welfare, and evaluating the adaptability of system models to other pollutants and forest types.

Methods and Monitoring Techniques:

The study was divided into a number of ecosystem components, with teams of scientists conducting individual studies which were then integrated into a larger system model. The ecosystem components measured were the physical-chemical properties of soil, regional climatological conditions including windflow and precipitation, photochemical oxidants (monitored annually), status and health of vegetation communities, decomposition processes, and small mammal population dynamics. Eighteen study plots were set up in a gradient from high to low oxidant levels. Conceptual models were developed for the various ecosystem components including a number of submodels for forests (tree moisture, oxidant flux-canopy response, tree growth, pests, and pathogens).

Major Results and Conclusions:

This study was one of the earliest ecosystem studies that attempted to describe the effects of an air pollutant on an entire ecosystem. It documented factors affecting and contributing to the decline in ponderosa pine and Jeffrey pine (*Pinus jeffreyi*) in the San Bernardino Mountains. The effects of other natural stress factors, such as defoliating insects and root pathogens, were enhanced by photochemical oxidants. Forest areas with different topographical conditions, such as precipitation patterns, were affected differentially by oxidants. A gradient of chronic injury in ponderosa and Jeffrey pine was correlated with oxidant concentration. The deciduous California black oak (*Quercus kelloggii*) was a useful indicator of the rate of injury development. Under the worst case, it is predicted that continuous subjection of these forest stands to the combination of ozone and periodic fires would result in an irreversible conversion to a less desirable (in terms of visual appeal, merchantable commodities, and recreational opportunities) oak-brush cover.

An Integrated Lake-Watershed Acidification Study (ILWAS).—

Ecosystem Type/Location/Duration:

Three forested watersheds, located in northern hardwood-spruce-fir forest; Adirondack State Park, NY; started in 1977 and completed in 1984 (Tetra Tech, Inc. 1984).

Pollutant Type/Source:

Acid deposition from regional sources.

Objectives:

To develop a tool to assess the amount of acidification that can or has occurred as a result of atmospheric deposition.

Methods and Monitoring Techniques:

The acid-base chemistry and hydrology of three watersheds and lakes (Woods, Sagamore, Panther) were monitored and measured for 4 years. The system was divided into a number of components including atmosphere, canopy, snowpack, vegetation, soil, bogs, streams, and lakes. These data, along with related meteorological data and laboratory experimental findings, were used to develop and test a mechanistic simulation model that calculates rates of change in the acidity of surface water as a function of changing atmospheric deposition levels.

Major Results and Conclusions:

The ILWAS study was a research project designed to develop a tool for relating the amount of acid deposition to lake acidity, factoring in watershed biogeochemical processes. It was not an environmental assessment as such. The results showed that the acid-base status of lakes is determined by the interaction of many factors including soil, hydrology, vegetation, geology, climate, and atmosphere. A factor's role can vary both geographically and temporally and must be viewed in terms of the ecosystem of which it is a part. The rate at which hydrologic basins supply alkalinity to through-flowing water establishes the vulnerability of lakes to acidification. In lake ecosystems isolated from alkaline rock by impermeable soils, the alkalinity source is removed. The model developed is intended for use in assessing the vulnerability of surface water to acidification by atmospheric acids and determining effective management strategies for acidic surface waters. Studies are currently underway to test and increase the geographical utility of the model in such areas as Wisconsin, North Carolina, and California. A 4-year study, funded by the Electric Power Research Institute, was recently initiated to evaluate the role of acid deposition in producing changes in nutrient cycling. The study will be conducted at forested sites in the Northeast (Whiteface Mountain), Northwest (Cascade Mountains), and the Southeast (Smoky Mountains) (Bondietti and others 1985).

UNDERSTANDING AIR QUALITY CONDITIONS IN WILDERNESSES

In an attempt to meet the objectives of this conference, a survey was made of the Class I areas to determine the status of air quality conditions and to identify ongoing research and future ecological research needs related to air quality. This survey was conducted by contacting the Class I area personnel and asking to speak to the air quality specialist, or the manager if no specialist was known. Ninety-seven of the 158 Class I areas were contacted (appendix). Of the Class I areas contacted, 20 percent indicated that ecological effects from air pollution had been documented (table 14). A larger number (47 percent) felt that future air quality effects were likely. Over a third (37 percent) of Class I areas surveyed had been involved in a PSD permit review. A majority of the Class I areas (78 percent) were able to identify "existing air quality influences."

Several studies, including our survey, indicate that wildernesses are already affected by a decline in air quality. Federal land managers surveyed were able to identify existing and potential air quality sources influencing their Class I areas (table 15). Class I areas in the Eastern United States are perceived to be influenced more by

Table 14.—Documented ecological effects to Class I areas as reported by Federal land managers

Documented effects	FWS[1]	FS[1]	NPS[1]	All
	Number of areas			
Yes	2	5	[2]12	19
No	16	55	2	73
Unknown	1	1	0	2

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

[2]Bennett (1985b) reports over 20 NPS lands have documented effects.

Table 15.—Percentage of identified existing and future air pollution influences for Class I areas

	Eastern U.S.		Western U.S.	
Sources	Existing	Future	Existing	Future
Natural	8	12	28	11
Point	60	70	31	49
Regional	32	18	41	27

point sources than regional sources. In the West, regional sources are now considered to be major influences, but point sources are expected to be a more important future problem. Natural sources (for instance, forest fires) also affect air quality in the West and are viewed to have a continuing importance although less so in the future.

Ten national parks have been found to have extensive damage to vegetation from ozone and sulfur dioxide (Bennett 1985b). The Park Service has developed a sensitivity rating of parks to air pollution (Bennett and others, this proceedings). Although this rating was developed for setting research priorities, it is indicative of the potential vulnerability of parklands (including wildernesses) to air pollution. Armentano and Loucks (1983) evaluated 10 national parks and other Federal lands with regard to air pollution. Ozone and acid rain effects have been demonstrated in the majority of these areas. Potential effects from SO_2 and ozone are predicted in the remaining areas. Based on these and other studies it can be concluded that wildernesses in the Eastern United States are presently being affected by ozone and acid deposition and in some locations possibly by SO_2. In the Western United States ozone is a real threat, especially to wilderness areas in California. Acid deposition is presently being evaluated in a number of western regions and appears to be a potential threat to wildernesses.

Although not all Class I areas were contacted, a number of conclusions can be drawn regarding the air quality conditions of wildernesses and the Federal land manager's role and understanding in protecting them from air pollution. The Clean Air Act and its amendments of 1977 set a procedure for protection of Class I wildernesses and delegated authority to Federal land managers for this protection. After 8 years there still appears to be a large number of Class I areas for which little progress has been made in developing and collecting AQRV baseline information, as well as air quality monitoring information. Many Federal land management personnel are generally unfamiliar with air quality effects. Because of the activity of the Air Quality Division, the Park Service personnel showed a greater understanding of air quality issues affecting their areas. This understanding is also reflected in the amount of air quality research being conducted in Park Service units (Bennett 1985b). In contrast to other agencies, each Park Service Class I area had an air quality specialist, usually a member of the Resource Management staff.

Differences exist in the ecological resources of the Class I areas that different agencies manage, and these differences may affect the degree of air quality understanding. For example, the Forest Service and Park Service manage Class I areas with the greatest diversity of ecosystem types, ranging from glaciers to deserts, with forests being the most common (table 16). The Fish and Wildlife Service's Class I areas are not only fewer in number but are primarily water related (riparian and wetland ecosystems), although forests do make up a significant number of the ecosystem types. The areal extent and proximity to industrial and urban development have not been correlated at this time, but these are also considered to affect the understanding reflected in the survey. When questioned about known air pollution influence, Class I area managers most frequently mentioned urban emission sources and regional haze as the top two air quality influences to their lands (table 17). Urban and

Table 16.—Major ecosystem type of surveyed Class I areas

Ecosystem type	FWS[1]	FS[1]	NPS[1]	All
Glaciers	—	2	1	3
Alpine	—	20	4	24
Subalpine	1	21	4	26
Forest	5	47	12	64
Chaparral	2	2	—	4
Desert	—	3	2	5
Grassland	6	3	2	11
Riparian	4	6	1	11
Wetland	8	—	1	10
Other	3	—	2	5

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

Table 17.—Reported major air quality influences on surveyed Class I areas

Air quality influences	FWS[1]	FS[1]	NPS[1]	All
None	5	16	2	23
Regional haze	—	13	5	18
Industry	4	—	—	4
Mining	1	6	1	7
Powerplants	2	4	1	7
Urban sources	4	14	6	24
Mills	—	5	5	10
Other	7	21	5	33

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

industry sources were the most frequently mentioned by the Fish and Wildlife Service. The next most important sources, in descending order, were mills, mining, and powerplants. The "other" category included wildfire, prescribed burning, and agricultural dust. Whether wildfire and prescribed burning, from an air quality point of view, are significant factors affecting ecological systems in wildernesses is not known. However, these factors, along with agricultural dust, were the most frequently identified as affecting air quality (table 17). Their influence on visibility is known. Twenty-three managers were not aware of any air pollution influence on their Class I lands.

When questioned about documented ecological effects, the majority of Federal land managers indicated that they were unaware of such effects; only 20 percent indicated the availability of any records (table 14). This was particularly true for both the Fish and Wildlife Service and Forest Service. Twelve of 15 Park Service units contacted indicated that they had documented effects reflecting a decline in conditions and the number of sponsored research programs.

There was greater involvement in the PSD process than in documenting effects, possibly indicating concern about future pressures from development. A greater proportion of Fish and Wildlife Service and Park Service units had been involved in PSD review than the Forest Service (table 18). The Air Quality Division of the National Park Service acts as a centralized receiving group for PSD applications involving their Class I areas. They also assist the Fish and Wildlife Service in this review. Table 18 indicates that about one-quarter of the Class I areas surveyed have been involved in the PSD process. This is a conservative estimate because not all National Park Service Class I areas were surveyed. Since 1977, the Air Quality Division has reviewed more than 120 PSD permit applications for Park Service lands and 30 to 35 for Fish and Wildlife Service land (Scruggs 1985). Information was not available as to how many Class I areas these reviews represented except that a number have been for the same Class I areas over the last 10 years. As mentioned earlier, Forest Service personnel contacted were less familiar with the PSD process than were NPS and FWS personnel.

Table 18.—Prevention of significant deterioration (PSD) reviews involving Class I areas in survey

PSD review	FWS[1]	FS[1]	NPS[1,2]	All
Yes	6	13	7	26
No	11	42	7	60
Unknown	0	10	1	11

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.
[2]Only a portion of NPS Class I areas surveyed.

Most of the Federal land managers did identify some AQRV's for their Class I lands (table 19). Of those that did, the majority identified the visibility AQRV. This AQRV is an indicator that has been specifically promoted by EPA. The Forest Service and the Park Service have identified a number of other AQRV's including flora and fauna, wildlife, fisheries, odor, and geology.

Table 19.—Identified air quality related values (AQRV's) of surveyed Class I areas

AQRV's	FWS[1]	FS[1]	NPS[1]	All
None	10	44	3	57
Visibility	7	19	12	38
Wildlife	—	6	3	9
Flora/fauna	1	7	4	12
Fisheries	—	3	2	5
Odor	—	4	—	4
Geology	—	3	—	3
Other	—	4	1	5

[1]FWS = Fish and Wildlife Service; FS = Forest Service; NPS = National Park Service.

The results of our survey indicated that the primary research and monitoring presently being conducted in Class I areas is related to visibility. Ecological research related to air pollution effects in wildernesses is limited to only a few Class I areas (less than 15 percent) and deals primarily with the responses of selected sensitive plant species. Excluding visibility studies, the most ecological research associated with wildernesses is carried out by the National Park Service and the least by the Fish and Wildlife Service. However, this is influenced in part by the fact that these two Federal agencies have a memorandum of understanding for air quality activity, with the work being conducted through the Air Quality Division of National Park Service.

AIR QUALITY/WILDERNESS ISSUES AND RESEARCH NEEDS

Detection or even recognition of change or damage in wildernesses presents a challenge to scientists. Distinguishing ecotoxic effects is difficult even in systems that can routinely and easily be monitored or otherwise instrumented for study (Butler 1978; Sheehan and others 1984), but the definition of wilderness and its inherent restrictions provide particular problems for scientific study. Not only must spatial and temporal variation be monitored, but detection of fluctuation outside of the norm must be determined for both acute and chronic situations of air quality degradation. This must be accomplished without impact on the wilderness concept. Without this information, the manager is unable to determine what effects are taking place or what potential effects may occur under certain air quality scenarios. Given the recorded effects and sensitivity of National Park ecosystems to air pollution (Bennett and others, this proceedings), some wildernesses can be expected to be affected by regional air pollution. Basic air quality monitoring information is still lacking for wildernesses and existing air pollution models are not accurate for the long distances associated with transport of pollutants.

Detailed studies in surrogate ecosystems and remote sensing or other forms of nonintrusive monitoring may

provide alternatives for wilderness research. Variables to be measured or monitored should focus on those indicative of the overall condition of the ecosystem and comparable over a variety of ecosystems. These should be easily and reliably measured and related to variables used in quantitative or modeling studies (Miller 1984). Because of their usual remoteness, wildernesses are most likely to encounter sublethal stress from air pollutants rather than acute effects. Therefore, the study of bioaccumulative responses is perhaps of highest priority. Techniques must be capable of addressing the mixture of air pollutants that is likely to exist (oxidants and sulfates, for instance), rather than the single-species response to an individual air pollutant. Methodology must be directed toward ecosystem scale analysis (Myers and Shelton 1980).

The complexity of the air quality issue in wildernesses has been indicated in a number of recent situations. Perhaps one of the most pertinent involved the Boundary Waters Canoe Area Wilderness (BWCA) and the Voyageurs National Park (VNP). An 800-megawatt, coal-fired powerplant was proposed for construction in Ontario, Canada, about 38 miles from the northern edge of the BWCA in Minnesota. The situation involved potential transfer of air pollutants across an international border and potential effects in these pristine ecosystems (Glass and Loucks 1980). This controversial case is particularly interesting because it not only involved a wilderness but was one of the first to deal with the deposition pattern of emissions from a point source and the use of a time-varying grid model with provisions for atmospheric transformation (acid precipitation). Although the powerplant was not built, the case pointed out the difficulty in determining sensitive receptors and predicting significant consequences of potential increased loadings of sulfuric and nitric acids and other combustion byproducts at distant sites.

Although potential point source effects on wildernesses can be regulated, the growing air quality impact of regional nonpoint source pollution, such as acid rain or oxidants, is not regulated. States, EPA, and Federal land management agencies need to address this problem if regional air quality effects of certain wildernesses (as well as other protected areas such as national parks) are to be minimized or eliminated. Also there is no mechanism for revising the PSD decision if new data become available indicating different air quality conditions (Yuhnke, this proceedings).

Research to determine sensitive receptors may in itself create a problem. For example, as part of the Federal research effort to assess the current and potential impact of acid deposition, a national surface water survey is underway (Brakke and others 1985). This three-phase project seeks to document the chemical and biological status of a representative sample of lakes and streams. To be representative, the sampling must include some wildernesses, but because the sampling approach may include use of motorized equipment or aircraft, there are potential conflicts with the strict application of the wilderness concept. In Washington State, for example, 59 of the 131 lakes proposed for sampling are in wildernesses. Access, even for scientific purposes and potential benefit, may establish an undesirable precedent.

The importance of this type of research, monitoring, and establishment of baseline conditions in wildernesses is evident again when attempting to determine "adverse impacts." In the case of the Clean Air Act and its amendments, the definition of adverse impact is left to the Federal land manager. The dilemma, then, is one of detecting and quantifying an effect without imposing on the naturalness of the area. The most sensitive receptors must first be identified. In wildernesses this may be difficult because there is often a paucity of air quality-related information on species most likely to be impacted, those in the alpine and subalpine life zones (Haddow 1984). If the information is available, there must then be a determination of "adverse" effects. Rocky Mountain and Intermountain Regions of the Forest Service have adopted a position of identifying a level of acceptable change (LAC) for each sensitive receptor for each air quality-related value in a wilderness. They interpret any predicted or measured change exceeding the LAC as adverse (Haddow 1984). This strict interpretation that any measurable effect is adverse will require careful selection and development of sensitive receptor monitoring systems. A recent Forest Service workshop dealt with these questions (USDA FS 1984).

The survey of Federal land managers of Class I lands, including a number of wilderness areas, reveals an uneven understanding by the managers of air quality effects, including the legislated authority to evaluate and protect sensitive environmental resources in their jurisdiction. Managers need training in basic air quality effects considerations, monitoring, and bioindicator theory. In addition, the need for a better understanding of the manager's role in the PSD review process is evident. Overall, very little progress has been made, except for the visibility AQRV, in developing and identifying AQRV's for Class I wildernesses. We suggest that such a system must be developed if these areas are to be adequately protected as prescribed by the Wilderness Act. The direction the Forest Service is taking in developing protocols for subalpine areas is a good model (Fox, this proceedings) and might be extended to all wilderness ecosystems.

Redesignation of Class II wildernesses to Class I status needs consideration. Presently Class I wilderness is afforded greater protection than Class II areas, although the policy of the Wilderness Act that created all wildernesses requires the most stringent protection of environmental quality, including the air resource. A potential policy conflict exists in enforcement of wilderness protection, Class II areas, and the Clean Air Act.

This conference and the creation of a National Wilderness Research Foundation are important steps in developing the research and information to meet these needs. Coordination of research efforts among Federal agencies, States, and the private sector is critical. Precedent for this type of integration is set by the current Federal interagency research program on acid precipitation and the interagency cooperation between the National Park Service and the Fish and Wildlife Service on air quality permit reviews. Developing a network of cooperative and coordinated projects will enhance opportunities for long-term support of both research and monitoring activities, which are necessary for impact analyses and ensuring preservation of wildernesses.

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APPENDIX: LIST OF CLASS I AREAS SURVEYED

Responsible Agency	Class I area
U.S. Fish and Wildlife Service	Chassahowitzka
	St. Marks
	Okefenokee
	Breton
	Mingo
	Swanquarter
	Cape Romain
	Red Rock Lakes
	Medicine Lake
	U.L. Bend
	Wichita Mountains
	Bosque del Apache
	Salt Creek
	Seney
	Lostwood
	Brigantine
	Bering Sea

(con.)

Responsible Agency	Class I area
National Park Service	Glacier
	Grand Teton
	Yellowstone
	Zion
	Craters of the Moon
	Shenandoah
	Voyageurs
	Grand Canyon
	Sequoia
	Acadia
	Bandelier
	Everglades
	Great Smoky Mountains

Forest Service	Forest	Area
	Nez Perce	Hells Canyon
	Sawtooth	Sawtooth
	Beaverhead	Anaconda-Pintlar
	Flathead	Bob Marshall
		Mission Mountains
	Kootenai	Cabinet Mountains
	Helena	Gates of the Mountain
		Scapegoat
	Bitterroot	Selway-Bitterroot
	Tonto	Mazatzal
		Sierra Ancha
		Superstition
		Pine Mountain
	Coconino	Sycamore Canyon
	Gila	Gila
	Carson	Pecos
	Lincoln	White Mountain
	Santa Fe	San Pedro Parks
	White River	Eagles Nest
		Flat Tops
		Maroon Bells
	Gunnison	LaGarita
		West Elk
	Routt	Mount Zirkel
		Rawah
	Rio Grande	Weminuche
	Fremont	Gearhart Mountain
	Siskiyou	Wild Rogue
		Kalmiopsis
	Winema	Mountain Lakes
	Mt. Hood	Mt. Hood
	Umatilla	Wenaha-Tucannon
	Mt. Baker-Snoqualmie	Alpine Lakes
	Okanogan	Pasayten
	Gifford Pinchot	Mount Adams
		Goat Rocks
	Cleveland	Agua Tibia
	Lassen	Caribou
	Sequoia	Dome Land
	Eldorado	Desolation
		Mokelumne
	Stanislaus	Emigrant
	Inyo	Hoover
	Sierra	John Muir
		Kaiser
	Klamath	Marble Mountain
	Modoc	South Warner
	Mendocino	Yolla Bolly-Middle Eel

(con.)

Responsible Agency		Class I area
Forest Service	**Forest**	**Area**
	Superior	Boundary Waters Canoe Area
	Mark Twain	Hercules-Glades
	White Mountain	Great Gulf
		Presidential Range
	Green Mountain	Lye Brook
	Monongahela	Dolly Sods
	Bankhead	Sipsey
	Ouachita	Caney Creek
	Ozark	Upper Buffalo
	Apalachicola	Bradwell Bay
	Chattahoochee	Cohutta
	Pisgah	Linville Gorge
		Shining Rock
	Cherokee	Joyce Kilmer-Slickrock
	Jefferson	James River Face

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RESEARCH ON SOIL AND VEGETATION IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

David N. Cole

ABSTRACT

This paper deals primarily with research on soil and vegetation impacts caused by recreational use of wilderness. Studies have documented the most obvious effects of trampling, described conditions on campsites and along trails, described the spatial distribution of impact, and documented changes in impact levels over time. Relatively little is known about the effect of trampling on soil biota and plant physiology or the impact of recreational stock. Lack of theoretical work and the short time frames of most studies leave us with little ability to evaluate the significance of most of the impacts that have been described. An increasing number of studies have examined the importance of factors that influence amount of impact. A considerable amount of research on the relationship between amount of use and amount of impact has consistently shown the relationship to be highly curvilinear. Impact generally occurs rapidly and can be severe even on lightly used sites. The exact nature of this relationship varies with type of use, environmental conditions, and impact parameter. Different environments vary considerably in their resistance and their resilience. Few studies have differentiated impact by type of user, however. There has also been a limited amount of applied management-oriented impact research, mostly in the areas of development of monitoring techniques and experimentation with techniques for rehabilitating damaged recreation sites. There is a need for more longitudinal studies, more specialized, detailed studies, more interdisciplinary approaches, and an expanded regional coverage. Current high-priority research needs are identified. Such studies are unlikely to be conducted until careers in the field become available.

INTRODUCTION

Wilderness soil and vegetation have been the subject of two rather distinct types of research. In the first type, natural soil and vegetation conditions and processes are studied. The primary objective of this line of research is to improve our understanding of the structure and function of natural ecosystems. The second type of research is focused more narrowly on human-caused changes in soil and vegetation conditions in wilderness and how best to manage these impacts. The primary objective of this second type is to help managers with the difficult task of preserving natural conditions in wilderness. Major agents of change in wilderness include air pollution, fire, nonrecreational grazing, mining, introduced plants and animals, and recreational use. Many of these research topics are discussed in detail in review papers on basic ecological processes, air, fire, and fish and wildlife; others have been the subject of very little research. I will only briefly comment on and cite a few examples of most of these lines of research and focus primarily on research on the impact of recreational use on soils and vegetation (fig. 1).

RESEARCH ON WILDERNESS SOIL AND VEGETATION CONDITIONS AND PROCESSES

Wilderness has been used as a natural laboratory for studying undisturbed soil and vegetation conditions and processes. (Throughout this paper, when I use the term "wilderness" I mean both legally designated wilderness and large nonroaded areas.) Due to their large size and a management regime that stresses preservation of natural conditions, wildernesses provide unique opportunities for basic biological research. Wilderness is particularly valuable for research that seeks to integrate complex elements of the ecosystem or that aims to classify and characterize natural plant communities. But wilderness is also an appropriate location for detailed, small-scale studies. For example, topics of papers presented at the Second Conference on Scientific Research in the National Parks ranged from extensive integrative studies (such as "Interactions Among Fluvial Processes, Forest Vegetation, and Aquatic Ecosystems, South Fork Hoh River, Olympic National Park, Washington") to small-scale studies (such as "Demography of *Salix setchelliana*—a Prostrate Willow of Alaskan Gravel Bars").

In most cases, studies are conducted in wilderness because wilderness provides the best opportunities for studying minimally disturbed soil/vegetation components. Undisturbed wilderness conditions also provide a baseline for evaluating the nature of human influences outside wilderness. The primary object of study is not the wilderness as such, but conditions that increasingly can only be found in wilderness. This is a major feature distinguishing this type of research from impact-oriented research. Such research can contribute to improved management of wilderness, however, even if this is not the primary goal. An improved understanding of the structure and function of natural ecosystems helps managers evaluate the significance of human disturbances.

Some of the best examples of basic ecological research that both capitalize on the unique characteristics of wilderness and also strive to make results applicable to management are the "pulse" studies that Jerry Franklin

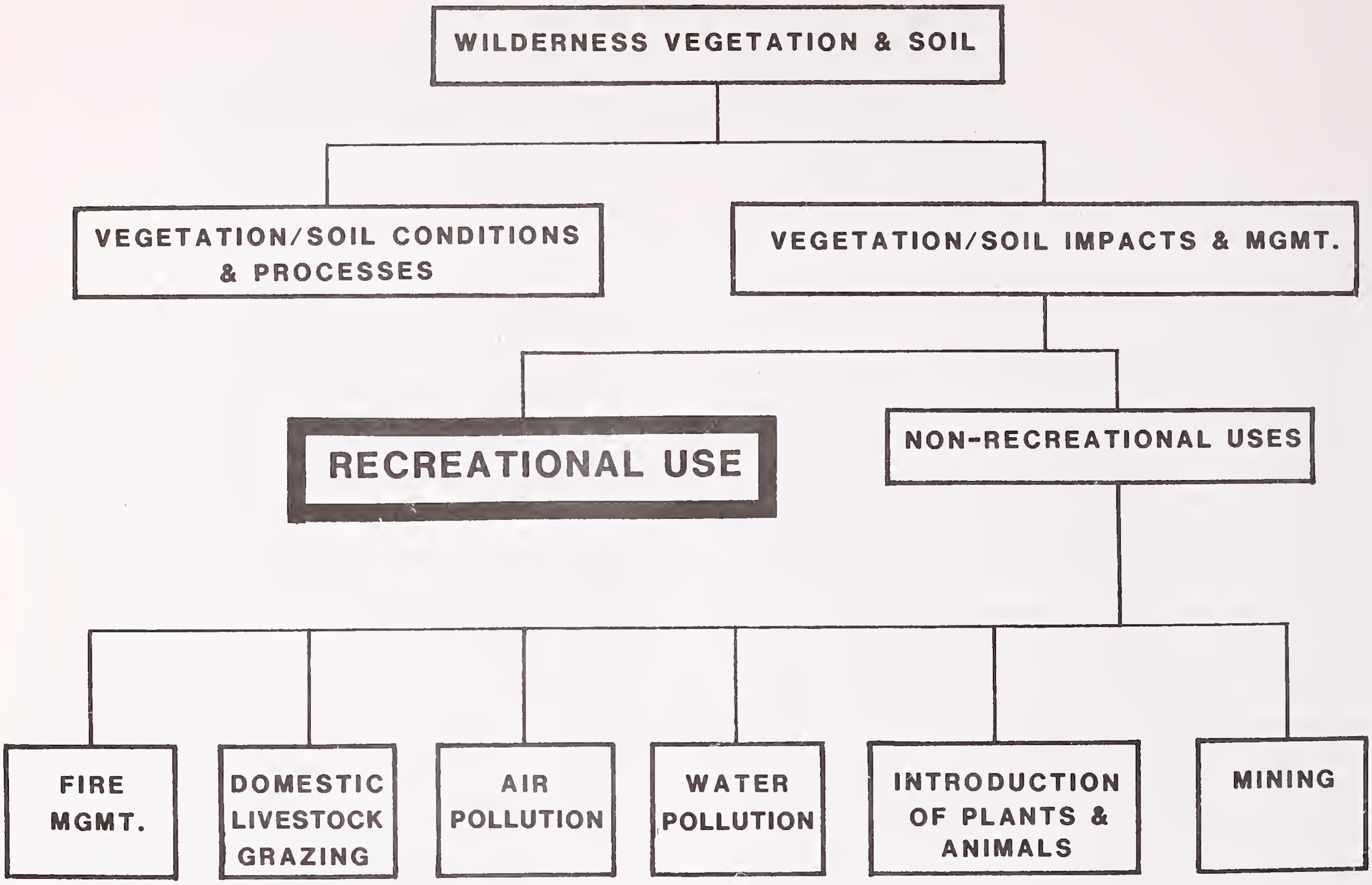

Figure 1.—Major types of research under the general heading of research on wilderness vegetation and soil.

has directed in Olympic and Sequoia/Kings Canyon National Parks. These studies bring together scores of specialists to measure, monitor, record, and then interact in such a way that linkages between ecosystem components are highlighted. Both studies have provided a wealth of basic ecological information. The Olympic study, for example, furthered the emerging recognition of the significant functions of woody debris—both on land and in stream channels—and provided a better understanding of disturbance agents in an environment that had been inadequately studied (Franklin and others 1982). A better understanding of the importance of woody debris as a seedbed and the effects of Roosevelt elk grazing on vegetation will help Park managers in their attempts to preserve natural conditions.

Most basic ecological research in wilderness could contribute to improved wilderness management. To maximize these benefits, however, communication between managers and researchers needs to be improved. Researchers can help by identifying potential management applications in the study design phase and by striving to highlight management implications. Managers can help by identifying information needs and communicating these to researchers.

Beyond these studies that contribute—often serendipitously—to management, all wildernesses need baseline and inventory information. Information is needed to (1) classify ecosystems, (2) map their distribution, (3) describe their basic characteristics, and (4) identify their dynamic properties and the factors affecting their dynamics (Franklin 1978). Information of this type is scarce. One of the few places where such information has been collected in a systematic manner is at Mount Rainier National Park (Moir and others 1979). A number of other National Parks have vegetation maps, data characterizing vegetation types, and permanent plots for monitoring trends, but other agencies with wilderness management responsibilities have little information of this type. The Forest Service, for example, is heavily involved in classifying vegetation in roaded areas and spends large sums of money every year for timber stand examinations and inventory. But little of this effort is directed toward wilderness, despite specific direction in the Forest Service Manual (FSM 2322.1) stating that wilderness management plans will (1) "describe the current condition of all resources and biotic associations"; (2) "describe the interrelationships of all resources, existing uses and activities, and highlight unique ecological

situations"; and (3) "identify problems associated with maintaining an enduring wilderness resource and the reasons for the problem."

Of particular utility to management would be a classification system stratifying the land into units that respond similarly to disturbance agents that managers might want to control. Since susceptibility to disturbance varies greatly across the landscape, managers must understand and be able to communicate this variability. In an attempt to parallel current efforts by foresters to develop timber management guidelines for different habitat types (see, for example, Pfister and others 1977), Cole (1982a) classified the vegetation of a portion of the Eagle Cap Wilderness in Oregon. Drawing on observations, vegetation sampling along trails and in campsites, and analysis of stand structure, each vegetation type was characterized as to its suitability for trails and campsites, the likely effects of fire suppression, site rehabilitation potential, and other likely management problems. Although limited in scope, this attempt illustrates the potential value of a land stratification system for organizing and communicating information on how best to manage various land types.

Another attempt to incorporate knowledge about the capabilities of different land types comes from Sequoia/Kings Canyon National Parks. Meadow types were classified and then studied to determine their potential to support recreational grazing (DeBenedetti and Parsons 1983). As a result of this research, Park managers have proposed a recreational grazing plan that (1) is sensitive to annual variation in climate, (2) considers the nature of specific meadows, and (3) is sensitive to the inherent ability of individual species to withstand grazing and trampling. Other offshoots of the program that will become increasingly valuable with time are a monitoring program and the designation of selected meadows representative of each major meadow type to be protected from all stock use, to serve as benchmarks for comparison with grazed meadows.

Clearly there is much value in basic research into ecological conditions and processes—both to the advancement of biology and to the management of wilderness. The keys to maximizing value lie in analyzing the information needs of individual areas, promoting the use of wilderness for biological research, and increasing commitment for the basic inventory and monitoring needed to meet even the most fundamental wilderness goals.

RESEARCH ON SOIL AND VEGETATION IMPACTS

Across the wilderness system as a whole, the agents of change associated with human activities that have most affected natural vegetation and soil conditions are probably fire and grazing of domestic livestock. The effects of fire suppression, including longer intervals between fires, buildup of fuels, and unusually large catastrophic fires, are expressed across vast wilderness acreages. Future attempts to return fire to a more natural role, either through allowing selected fires to burn or through scheduled ignitions, will also affect vast acreages. Research into the natural role of fire, its effects, and its management has been one of the most active fields in wilderness research. Refer to the review paper presented in this conference by Bruce Kilgore for more detail.

Although not well documented, impacts of domestic grazing animals, particularly cattle and sheep, have been pronounced in many wildernesses, particularly in the West (Vale 1977; Vankat and Major 1978). Many areas supported huge herds of animals during the late 19th and early 20th centuries. Although herds were cut back dramatically following recognition of unacceptable levels of deterioration, livestock grazing still occurs in over 40 percent of wildernesses (Washburne and Cole 1983).

Literature on the relationship between domestic livestock grazing, vegetation, and soils is extensive. Most of it is prescriptive, however, and little of it applies directly to wilderness. Descriptions of grazing effects on natural vegetation have been of secondary importance, although they do exist—even for wilderness areas (Reid and others 1980). With few exceptions, range management studies have had objectives of maximizing sustained production, with little regard for the "naturalness" of conditions. Wilderness management could be aided greatly by the development of management prescriptions that optimize both production and "naturalness." Managers of about one-quarter of the wildernesses with grazing feel it is a problem; most of these areas are located in the Southwest (Washburne and Cole 1983). This is a major research gap.

A unique opportunity to study grazing in wilderness settings was provided in 1982 when, as part of a bill to prolong grazing in Capitol Reef National Park, Congress directed the National Academy of Sciences to study grazing and its impacts at Capitol Reef (Public Law 97-341). A select committee of eminent scientists, after reviewing the situation in the field, talking with concerned parties, and examining available literature, proposed a research program. To do the job correctly, they estimated a budget of $930,000, to be provided by the National Park Service. The proposal has been shelved. The interesting thing about this example is that it provides an objective measure of the level of funding necessary to research this subject. Examples of what it would cost to conduct wilderness research correctly (as opposed to how much funding is available) are almost as rare as funding for such projects.

Air pollution has also affected the vegetation and soils of wilderness areas. For example, ozone effects on vegetation, including increased mortality of ponderosa pine, have been documented in the San Bernardino Mountains of southern California (Cobb and Stark 1970), where several National Forest wildernesses are located. "Acid rain" effects on forests similar to those in many northeastern wildernesses are currently the subject of considerable research. Baseline data, to monitor future effects of air pollution, are being collected in other areas, from Sequoia/Kings Canyon National Parks in the West to the Shenandoah and Great Smoky Mountains National Parks in the East. Refer to the review paper presented in this conference by Kent Schreiber and James Newman for more detail on air quality and its management.

The effects of introduced animals on vegetation have been an active subject of research, but almost entirely in the National Parks. For example, 20 papers (about 5 percent of those presented) at the Second Conference on Scientific Research in the National Parks were on introduced animals, their effects, and their management. Considerable attention has been focused on European wild boars in the East, feral pigs in Hawaii, burros in the Southwest, and nonnative mountain goats in the Olympics. In several cases, such as burros in Grand Canyon, this research has led to aggressive control measures. Conceivably much of the knowledge generated from these studies can be applied to wilderness managed by other agencies, but with no comparable research program.

Although less studied in wilderness, vegetation change has also resulted from the introduction of plants, such as salt cedar in riparian areas of the Southwest (Robinson 1965), and of diseases or insect pests, such as Dutch elm disease (Karnosky 1979) and the gypsy moth (Marshall 1981). Elimination of species, such as large predators, has also affected the biota, although again these effects are not well documented. Wilderness management can probably benefit from active research programs, particularly related to insects and disease, outside wilderness.

A final controversial source of change is mining. Only about one-third of all wildernesses have mining claims or developments (Washburne and Cole 1983), and effects on vegetation and soil where mining does occur are likely to be highly localized. Transportation systems may be more disruptive than the mining itself, although improper disposal of tailings can have widespread effects. Much research, outside wilderness, has been directed at minimizing and rehabilitating impact. However, important constraints in wilderness that make direct application of nonwilderness research problematic include the importance of "natural conditions," the lack of mechanized equipment, and the prevalence of extreme environmental conditions that make regeneration more difficult. Research analogous to that being done outside wilderness, particularly on methods for rehabilitating mining disturbances, could be extremely helpful to wilderness management.

Of the significant causes of impact on vegetation and soils, the cause with at least a modestly developed research base that is not being dealt with elsewhere at this conference is recreation. Recreational impacts are a significant problem, at least locally, in most wildernesses. They are more subject to management control than air pollution, for example, and they are the subject of a discrete discipline—recreational ecology. This discipline—its development, its methodologies, the results it has provided, its application, and its future—will be the focus of the rest of this paper.

DEVELOPMENT OF RECREATIONAL ECOLOGY RESEARCH

Beginnings

The field of recreational ecology is now over 50 years old. The earliest study I could find was an examination of recreational impacts on the California Redwood State Parks (Meinecke 1928). Similar nonrigorous descriptions of impact in recreation areas typified the state of the field, particularly in the United States, until the mid-1960's. Most of this work was conducted in the National Parks; examples include the documentation of packstock impacts in Sequoia and Kings Canyon National Parks by a series of researchers from Armstrong (1942) to Sumner (1968), of subalpine meadow damage at Mount Rainier (Brockman 1959), and of impact problems in Grand Teton National Park (Laing 1961; Merkle 1963).

During this same period of time, academic interest in the ecological effects of recreation developed. Lutz (1945) studied soil changes on picnic sites in Connecticut. Several theses—Thornburgh's (1962) study of soil compaction and vegetation change on backcountry sites in Mount Rainier National Park and what is now Glacier Peak Wilderness, Hartesveldt's (1963) study of soil compaction and growth of giant sequoia in Yosemite National Park, Willard's (1963) study of recreational impacts on alpine tundra in Rocky Mountain National Park, and Wagar's (1964) treatise on carrying capacity—were also completed. These studies were more rigorous and quantitative; they provided estimates of amount of change by comparing recreation sites with controls. They also employed a wider variety of measurement techniques. This set the stage for efforts to more thoroughly describe the nature and significance of recreational impacts. It is worth noting that these studies examined a wide range of situations along the recreational spectrum from heavily used roaded parks and picnic areas to remote campsites in wilderness.

Europeans were taking a somewhat different tack at this time. In England, particularly, most concern was with the impact of informal countryside recreation—strolling and picnicking in a rural setting. Compared with the United States, use levels were high but not as highly concentrated at such destination sites as designated picnic grounds or campsites. This difference may explain why early European recreational ecology studies were less likely to be descriptions of conditions on recreation sites. Instead they tended to focus on the effects of a more generic activity—trampling. This focus on activity, as opposed to site conditions, placed more emphasis on process and may explain why the Europeans moved more rapidly into the experimental phase of impact study.

Pioneering work along these lines was done by Bates (1935), in England. He described the conspicuous vegetational gradient perpendicular to trails—from bare earth, through a short vegetation of trampling-resistant species, to natural vegetation—noting that changes in species composition reflected differential tolerance both to direct mechanical injury of vegetation and to the indirect effects of soil change. His greatest contribution was probably his use of experimentation to examine the relative importance of these two mechanisms of change. Although none of the European literature deals with situations analogous to wilderness or backcountry, much of it contributes to our understanding of wilderness impacts due to this emphasis on the effects of trampling.

Early Development

These beginnings served to define the magnitude of the problem and outline many of the components in need of examination. This led to a period of time during the 1960's and early 1970's when research in recreational ecology, supported almost entirely by governmental agencies charged with managing recreational and natural areas, intensified. Early in the 1960's the most noticeable developments were in the United States. Developed campsite conditions and management were studied by a number of Forest Service researchers—Magill and Nord (1963) in California, Wagar (1965) and his associates in the Intermountain West, Ripley (1962) in the southern Appalachians, and LaPage (1962) in the Northeast. Cooperators at the University of Minnesota began a series of projects examining wilderness campsites in the Boundary Waters Canoe Area (Frissell and Duncan 1965). The National Park Service also sponsored a study of conditions on developed campsites in Rocky Mountain National Park (Dotzenko and others 1967) and how damaged sites can be rehabilitated (Jollif 1969).

These studies improved knowledge in three general areas: (1) the importance of factors that influence amount of impact, such as amount of use or environmental conditions (LaPage 1962; Ripley 1962; Wagar 1964; Frissell and Duncan 1965; Dotzenko and others 1967; McCool and others 1969); (2) change in campsite conditions over time (LaPage 1967; Magill 1970; Echelberger 1971; Merriam and others 1973); and (3) methods for improving vegetation conditions on deteriorated campsites (Jollif 1969; Cordell and James 1971; Beardsley and Wagar 1971; Cordell and others 1974; Beardsley and others 1974).

In Europe, research activity intensified in the late 1960's. Two conferences in 1967, one sponsored by Great Britain's Nature Conservancy (Duffey 1967), the other by the International Union for the Conservation of Nature and Natural Resources (1967), focused attention on the ecological effects of recreation. Two active centers of research were the Nature Conservancy's work on problems resulting from new ski developments on Scottish mountain tundra (Watson and others 1970; Bayfield 1971, 1973, 1979) and the work of Conservation Course students from University College, London (Speight 1966; Goldsmith and others 1970; Burden and Randerson 1972).

These studies were notable in their attempt to inject more rigor and quantification into recreational ecology. More elaborate experimental designs and techniques were developed, and there were some early attempts to use multivariate statistics. Liddle and Greig-Smith (1975), studying the effects of trampling on sand dune vegetation in Wales, followed in this tradition. They utilized experimentally controlled applications of trampling to develop mathematical models relating amount of trampling to consequent effects. On campsites in northern Michigan, Legg (1973) developed multiple regression equations that predicted level of impact on the basis of site factors—an extension of analytical techniques first used by Wagar (1964).

Another subject that received some work in the early 1970's was trail deterioration and its management. The vegetation on and along trails had been examined as early as Bates' (1935) study but primarily to better understand the effects of trampling. Ketchledge and Leonard (1970) provided an early estimate of erosion rates on trails in the Adirondack Mountains. More rigorous studies followed. Root and Knapik (1972) and Bayfield (1973), working in the Canadian Rockies and the Scottish Highlands, respectively, studied the relationship between trail condition and various site and design factors. Dale and Weaver (1974) looked at the relationship between trail width and depth and amount of use, whether use was by hikers only or horses and hikers, and whether the trail was located in meadow or forest.

Another research program that should be mentioned here is the series of studies undertaken between 1972 and 1975 by Parks Canada in the Canadian Rockies (for example, Landals and Knapik 1972; Landals and Scotter 1974). These reports were general assessments of impact problems, particularly on campsites and along trails, with recommendations for management. Although study methods generally lacked rigor and the reports were never published, this set of reports probably represents the most thorough assessment of impacts and their management available anywhere.

By the mid-1970's, then, the focuses of research concern had been established and a sizable quantity of research data had accumulated. The basic research questions being addressed were (1) what changes occur on campsites/picnic sites? (2) what changes occur on trails? (3) what changes result from trampling? (4) how do site conditions change over time? (5) how do impacts relate to use and environmental factors? and (6) how effective are certain management techniques at avoiding or rehabilitating impact? The first syntheses of the recreational ecology field also were compiled (Speight 1973; Goldsmith 1974; Liddle 1975a). With recreational use and consequent impact problems increasing greatly every year, it appeared that the field of recreational ecology was ripe for moving from its largely descriptive and uncoordinated adolescence into a more rigorous, focused, mature phase.

Recent Development

When we look at research activity in terms of number of publications, the late 1970's appear to be a "golden age" for recreation ecology. The total number of publications in the late 1970's was twice that of the early 1970's (fig. 2). However, this number was inflated by several conferences—two on scientific research in the National Parks and one on recreational impacts on wildlands. These three conferences generated almost one-third of the published papers in this period, and the vast majority of these papers offered only modified versions of data published elsewhere.

By the early 1970's, the Forest Service had terminated all of its earlier recreational ecology research programs. In fact, between the early 1970's and 1980, I could find

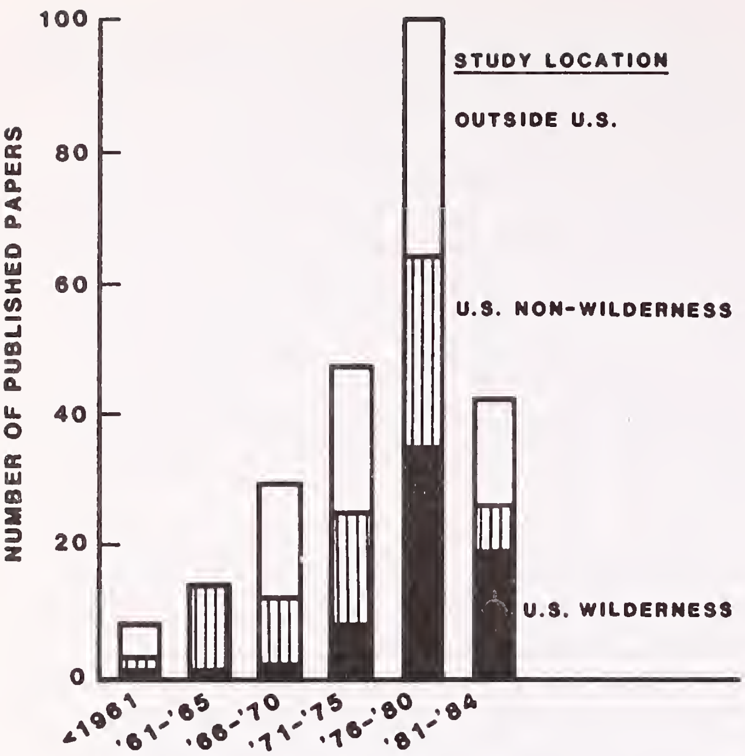

Figure 2.—Number of recreation ecology publications from various time periods. Papers in conference proceedings were considered publications, but theses were not.

published results from only two studies supported by the Forest Service—Helgath's (1975) study of trail erosion in the Selway-Bitterroot and Fay's (1975) test of fencing, fertilization, and liming as possible means of restoring vegetation to a backcountry camp in New Hampshire's White Mountains. The only other relevant papers are a haphazard collection of non-data-based papers on measurement and management techniques (Hendee and others 1976; Fay and others 1977; Leonard and Whitney 1977; Rinehart and others 1978; Frissell 1978). Most of the early researchers were still in Forest Service recreation research, but their focus had shifted to the social and planning aspects of recreation.

In contrast to the Forest Service, the 1970's was a period of growth in this field for the National Park Service. During this period recreational ecology papers resulted from supported work in Grand Canyon (Carothers and Aitchison 1976), Yosemite (Holmes and Dobson 1976; Malin and Parker 1976; Hecht 1976; Foin 1977; Lemons 1979), Sequoia/Kings Canyon (Parsons and DeBenedetti 1979; Parsons and MacLeod 1980), Denali (Stelmock and Dean 1979), Olympic (Schreiner and Moorhead 1976), Mount Rainier (Edwards 1979), and Great Smoky Mountains (Bratton and others 1978, 1979) National Parks, and Ozark National Scenic Riverway (Marnell and others 1978). Although somewhat more rigorous than the anecdotal work of the 1960's and before, these projects were largely descriptive. Objectives were usually to survey impacts over large areas. Although often quantitative in nature, only the most obvious impacts were examined, and generally neither measurements nor analyses were very sophisticated. This primarily represented an expansion of the regional coverage of impact studies. This increased coverage was valuable from the standpoint of being able to evaluate the general applicability of specific results; however, it did little to advance methodology or theory or to move the field toward a deeper plane of inquiry or understanding.

In addition to an expansion of regional coverage, Park Service studies looked, at least briefly, at two new sources of impact—campfires (Fenn and others 1976) and urine (Holmes and Dobson 1976).

Many of the papers published in the late 1970's were short-term, one-time studies by academics (for example, Hartley 1976; Coombs 1976; Jones 1978; Rutherford and Scott 1979). Presumably, students interested in the subject conducted these studies, with the assistance of a professor who found the subject an interesting change, and then both went on to do something else. New places were studied and new information was uncovered, but there was no building, coordination, or deepening of the field.

Many countries were involved in recreation ecology research by the late 1970's. Work continued in Great Britain but at a much reduced rate. Recreation ecology research was also done in Finland (Kellomäki 1977), the Netherlands (Boomsma and van der Ploeg 1976), Poland (Falínski 1975), Sweden (Byran 1977; Emanuelsson 1979), the U.S.S.R. (Rogova 1976; Kazanskaya 1977; Spiridinov 1979), Australia (Edwards 1977), and Canada (James and others 1979).

Generally reviewing the 1970's, we see expansion in the field of recreation ecology. Scientists from more countries were studying recreational impacts. Within the United States, increased interest on the part of the Park Service partially offset the demise of Forest Service research programs. All major lines of inquiry were advanced, and new ones, particularly the development and evaluation of management techniques and monitoring systems, appeared. The major problem was lack of continuity. The field remained dominated by short-term, one-of-a-kind studies that did not build on each other.

CURRENT STATE OF THE DISCIPLINE

In the 1980's, as managers of more and more wildernesses are struggling to deal with recreational impact problems, we would like to think that this field of inquiry is continuing to mature. Unfortunately, there is much to suggest that this is not the case. Productivity has dropped radically; from an average of 20 papers per year in the late 1970's, the rate in the early 1980's has dropped to 10 per year. Participation has dropped even more radically; of 44 papers I could find that have been published since 1980, 18 are by just two authors.

Within the Forest Service, currently about 20 professional scientists are doing recreation research. None of these researchers emphasize recreational ecology. Reviewing Forest Service recreation research publications between 1961 and 1982, I found only 33 out of 932

references (3.5 percent) dealing with recreation impacts and their management. This compares with 100 on visual resource management, 94 on user descriptions, preferences, and benefits, and 62 on how to assess use. The Forest Service does support recreational ecology research by outside cooperators; however, such research has been conducted in only five wilderness or backcountry areas.

A similar situation exists in the Park Service, although here the emphasis is on basic biology rather than social research. Of the papers presented at the Second Conference on Scientific Research in the National Parks in 1979, 5 percent dealt with impacts of recreation on the natural environment. This compared with 5 percent for water, 5 percent for air, 12 percent for social recreation research, 13 percent for fire, and over 50 percent for basic biology.

It is more difficult to assess participation outside these agencies. No one in the U.S. Department of the Interior, Fish and Wildlife Service or Bureau of Land Management appears to be doing recreation impact research. Moreover, research by the academic community is sporadic at best. I could find only 50 authors (or groups of authors) who have reported—in published or unpublished form—data-based research on recreation impacts in wilderness/backcountry settings. Only 10 of these 50 participated in more than one study.

This limited participation would be understandable if ecological impacts and their management were not a problem. However, this is clearly not the case. We conducted a survey of managers of all existing wildernesses and many likely additions to the wilderness system in 1980 (Washburne and Cole 1983). Our results corroborated those of an earlier sample of 35 wilderness managers (Godin and Leonard 1979), finding that recreational impacts, particularly on trails and campsites, were the most common wilderness management problem in the eyes of managers.

Outside the United States, the condition of the discipline is as bad—if not worse. Activity in the 1980's is less than at any time since the early 1960's. In 1983, I attended a conference on the ecological impacts of outdoor recreation in Europe and North America. Organized by the Recreation Ecology Research Group—a primarily British group that includes some of the first scientists to work in the field—the conference had the ambitious goal of bringing together most of the researchers in the field. From discussions with many of the attendees, it appears that only a couple of people in the world are currently able to pursue careers in recreational ecology research.

Perhaps the one bright point, from the perspective of this conference, is that a large proportion of the research in the 1980's has been in wilderness in the United States. Although recreational ecology is at its lowest ebb since the 1960's, more new studies in wilderness have been published since 1980 than in any other 5-year period. We now have published data on ecological impacts from nine National Forest wildernesses: Boundary Waters Canoe Area, Eagle Cap, Frank Church-River of No Return, Selway-Bitterroot, Lee Metcalf, Bob Marshall, Rattlesnake, Alpine Lakes, and Glacier Peak; from wilderness or backcountry in 13 National Park areas: Grand Canyon, Grand Teton, Great Smoky Mountains, Dinosaur, Mount Rainier, Denali, North Cascades, Olympic, Sequoia/Kings Canyon, Yosemite, Rocky Mountain, Guadalupe Mountain, and Ozark National Scenic Riverway; as well as from the Adirondack Mountains in New York, the Mission Mountains Tribal Wilderness in Montana, and the Green Mountains of Vermont (fig. 3).

Given that we now have about 90 million acres of wilderness, in over 450 different units, these 24 areas represent a meager start at even describing impact problems. The best represented parts of the system are, in order, the Boundary Waters Canoe Area (BWCA), the Northern Rockies, the Sierra Nevada, and the Pacific Northwest. Major gaps exist in the East, the Central States (except for the BWCA), the Southwest (except for the Sierra Nevada), and Alaska.

A problem that may be more significant than inadequate regional representation is the declining trend in research sophistication. An increasing proportion of papers are not based on data. There has been relatively little progress in the development of either theory or more sophisticated research techniques.

In a review of recreation ecology literature in Europe in 1976, Satchell and Marren stated:

> We found a great disparity between the relative abundance of data on recreational demand such as numbers, origins and attitudes of visitors, and the paucity of data on the ecological consequences of recreational activities . . . . We consider that the current level of research is not commensurate with the magnitude of the problem of reconciling the maintenance of amenity and conservation interest in areas used for public recreation with the demand for outdoor leisure pursuits in increasingly urban societies.

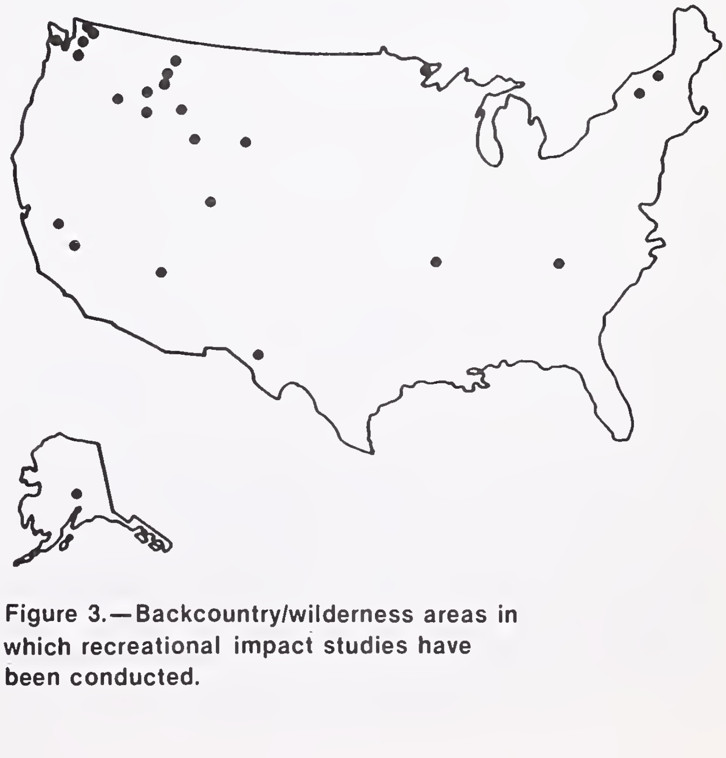

Figure 3.—Backcountry/wilderness areas in which recreational impact studies have been conducted.

Clearly these disparities are even worse a decade later—in Europe and in the United States.

In another review, Goldsmith (1974) wrote that most studies merely "record observations of a rather superficial nature and only a few describe specially designed experiments with detailed analysis of the resultant data." This situation has also not improved dramatically. Most research continues to merely document the obvious; time frames are short, theory is lacking, and few studies are comparable.

None of this is very surprising when a field is only the part-time interest of a few researchers. Even today there are essentially no careers available in recreational ecology. Only with the possibility of a career can we expect people to undertake the long-term work that is critically needed or to design complex studies that examine all the variables that influence impacts. Only then will studies build on one another or will students be able to get training in the field. Only then will it be possible to develop the critical mass necessary to stimulate creative thinking and the development of theory.

It has been suggested that the ecology of recreational impacts is known well enough and is seldom more than documentation of the obvious. This seems to me to be more an indictment of what the field has done than what it could do. Because support for this discipline has never solidified, the field is characterized by an ebb and flow of personalities all starting at a low level of sophistication and moving on to greener pastures before any significant advancement can occur.

RESEARCH METHODS

Study Designs

A variety of study designs have been utilized in recreational ecology studies. I choose to place them in four categories: descriptive surveys of recreation sites, comparisons of used and unused sites, before-and-after natural experiments, and before-and-after simulated experiments. Within each of these broad categories there can be tremendous variation in spatial and temporal scales, as well as the soil/vegetation parameters under study.

The simplest and, to date, the most common of these approaches is the descriptive survey of recreation sites (for example, Bratton and others 1978, 1979). Vegetation and soil parameters are measured or estimated to determine the current condition of the resource. Variability across an entire area can be assessed, and conditions can be compared to objectives to determine whether or not problems exist and management actions are required. Site conditions can be correlated with use and environmental conditions to suggest hypotheses of cause and effect. Conditions can also be followed over time to establish trends.

The two basic problems with this approach are that (1) there is no measure of impact or change and (2) it is difficult to evaluate cause and effect. Existing conditions are affected by a wide variety of environmental as well as use parameters. Fifty percent vegetation cover on a site may be perfectly natural, or it may represent a dramatic loss of cover. Without a comparison to undisturbed conditions, it is impossible to evaluate the effects of recreational use. Moreover, there is also the problem of very little information on what has actually happened to the sites under study. Recreational impact is variable from year to year, group to group, and site to site. Surveys of site condition, alone, are incapable of substantially improving our ability to predict the consequences of various types and amounts of use in various places.

The great value of these studies is in their immediate management utility. They can usually be completed relatively rapidly, without a high investment in training, and are useful in assessing the general condition of the resource and monitoring its change over time. Thus these studies can form the backbone of information needed to guide day-to-day management.

Another common research approach involves comparison of used and unused sites (for example, Cole 1982b). With this approach, ecological impact is estimated on the basis of a comparison between conditions on recreation sites and neighboring undisturbed sites (controls) with similar environmental settings. The implicit assumption is that the recreation site was similar to the control prior to use and, therefore, that any difference between the two sites is the result of recreational use. Once these estimates of change are obtained, it is a relatively simple matter to compare change on sites with different use and environmental characteristics—utilizing a cross-sectional design—in order to better understand how these affect amount and type of impact.

This is a very convenient and attractive approach because, in contrast to the previous approach, it does provide a measure of change. Moreover, changes—despite occurring over a long period of time—can be evaluated at one point in time; long study periods are not required.

However, two major sources of error exist that can make the results of this approach misleading. First, controls never perfectly replicate preexisting site conditions. Therefore some of the difference between recreation sites and controls is a result of environmental variability rather than recreational use. This problem becomes increasingly severe as local environmental variability and the uniqueness of sites selected for recreation use increase. In some situations it is also impossible to find controls that have not been affected by recreational use. Care in selecting controls and disqualifying sites without adequate controls will counter some of these problems. The environmental variability problem can be reduced with a large sample size, and its effect can be better interpreted with an evaluation of inherent variability between control sites.

Second, it is difficult to identify, let alone control, all the ecological and human-use variables that affect the amount of change occurring on a site. For example, a common objective is to assess the effects of amount of use on amount of impact. To do so requires accurate measures of use, which are seldom available. Even where current use can be assessed, there is little certainty that current use patterns reflect the past use history of the site. Moreover, the effect of amount of use is strongly

modified by type of use, timing of use, and the resistance of the site—all of which are difficult to assess and virtually impossible to control perfectly.

The solution to these problems is not to abandon this approach; rather, the solution lies in controlling variability as much as possible, studying the influence of these other variables, sampling as many sites as feasible, not exceeding the limitations of data in the analysis phase, and qualifying the final results. For example, rather than treating 1 year's use data as interval level data and regressing it against some measure of impact, it is much more realistic to establish discontinuous classes of use and use analysis of variance (for example, Marion and Merriam 1985). The analysis may be less sophisticated, but the results are less likely to be misleading. Similarly, unless the magnitude of statistically significant differences is great, researchers would be prudent to recognize the importance of uncontrolled variability and play down the importance of these differences.

Most of these problems are more effectively dealt with by using the longitudinal before-and-after natural experiment approach (for example, Merriam and others 1973). In these studies, site conditions are measured before use of the site commences and then after it has occurred. Changes identified in this way are more accurate assessments of recreational impact because the error caused by assuming a site was identical to a control is eliminated. Ideally, conditions will be measured periodically and over a long enough period of time for the effects of recreational use to equilibrate. If this is not done, this approach loses value because it will not be possible to predict the consequences of long-term use, the primary objective of most research. It is also important to follow changes on control sites in order to incorporate nonrecreation-related changes into the final interpretation of results. Finally, it is imperative to accurately evaluate both amount and type of use on the site. If this is not done—and it is extremely difficult to do in backcountry—this approach loses many of its advantages over the cross-sectional approach previously discussed.

A variation on this approach is to evaluate the effects of a change in use or management or both by taking measurements before and after the change. Examples might include examining the effect of packstock on a trail that had never had stock use before or recovery on a campsite that was being closed to all use (for example, Stohlgren 1982). Such natural experiments can be enlightening. However, they need to be undertaken under a wide variety of situations before it will be possible to evaluate the general applicability of results.

To get beyond entirely site-specific conclusions, longitudinal studies need to utilize factorial designs. For example, the effect of amount of use on sites located in various environments could be evaluated by stratifying sites environmentally and examining sites receiving a wide range of use. However, this brings out the primary disadvantage of this research approach—its cost, both in terms of time and money. Sites need to be measured periodically, probably at least once per year (and preferably more frequently) for at least 5 years. Use measurements need to be taken continuously over this time period. In backcountry this requires a lot of field time. Moreover, results will not be in hand for a long period of time. Finally, it is often difficult to find the real-life situations needed for the factorial design or to even predict which sites will fall into which use category to ensure sufficient sample sizes in all cells of the factorial design.

The common solution to all of these problems is the simulated experimental approach (for example, Weaver and Dale 1978). The major difference between this and the preceding approach is that the investigator plans the application of recreational use. This makes it much easier to find the situations to be examined in a factorial experiment. It also makes use measurement easier and more accurate, and it makes it easier to eliminate variability in parameters not under study, such as whether trail use is by horse or hiker, or whether use occurs when soils are wet or dry. Occasionally, this approach has involved dropping an artificial "foot" or rolling a corrugated roller along the ground. More frequently, the investigators trample areas themselves, walking back and forth at known rates.

To be of most value, it is important to take measurements before and after each treatment. Changes also need to be followed on controls. Even where this is done, local environmental variability will interject some error into estimates of recreation-caused change because the effects of a given amount of use will vary with the tolerance different species have for impact. To predict the long-term consequences of continual use, it is best to both apply use and measure impacts over a period long enough for effects to equilibrate. This is costly and has never been done.

A major drawback to this approach is that it seldom truly simulates the type of recreation use of concern to managers. It is much more directly applicable to problems of trail deterioration and dispersed trampling than to campsite damage. It would be possible for investigators to camp different numbers of times on different vegetation types and measure responses. This would be very costly, however, and there are still variables, such as weather conditions, that cannot be controlled.

Each of these approaches, then, has inherent advantages and disadvantages. The more scientifically rigorous approaches are more costly and time-consuming and less likely to simulate "real" conditions. The other options have more error in their estimates of recreational impact and are less capable of unraveling cause and effect. All approaches can provide valuable information. The key is to match the approach to the objectives and situations at hand, while carefully designing a study that minimizes the problems inherent to any single approach. Finally, most light will be shed on the subject by utilizing several approaches simultaneously. For example, descriptive surveys can help managers assess their current situation and provide baseline data for a monitoring program. Cross-sectional studies, in a factorial design, can suggest what factors managers might want to manipulate to minimize impacts. Long-term simulated experiments can explore these hypotheses in more detail to "fine tune" future management, while longitudinal studies are useful for evaluating the effectiveness of new management policies taken to counteract problems identified in the descriptive surveys.

With few exceptions, recreational ecology studies have only examined obvious impacts and have operated at an intermediate level of resolution. There have been few detailed studies of the process whereby a change such as a shift in species composition occurs. Likewise there have been few studies of interrelationships between ecosystem components affected by recreational use. This neglect of both process and interrelationships at the ecosystem level makes it difficult to evaluate the significance of recreational impacts in anything other than esthetic terms.

Vegetation and Soil Parameters

When describing vegetation response to recreation, most attention has been given to description of the community and damage to trees. Descriptions of morphological and physiological responses are much less common. Vegetation is usually sampled along transects or in plots of varying size and configuration and then described in terms of percentage cover of total vegetation and each species. Many studies have used these data to characterize species composition, diversity, and life or growth form spectra. Fewer studies report frequency, density, or biomass. Population structure has been described, for *Juncus trifidus*, by Pryor (1985). Fletcher and Shaver (1983) studied plant demography of disturbed *Eriophorum vaginatum* populations.

In forested areas, investigators commonly report frequency of tree damage and root exposure and density of tree reproduction. A few also have reported diameter class distribution and have observed apparent declines in vigor and growth rates.

The most frequently reported morphological parameters are vegetation height, growth form, and bud location. Several studies have also reported number of flowers per plant. In perhaps the most indepth description of morphology, Liddle (1975a) reported data on leaflet area for *Trifolium repens* and on number of tillers per plant, length of live tillers, number of live leaves per tiller, dry weight per shoot, and dry weight per tiller for *Festuca rubra*. Goryshina (1983) presented data on leaf area and cell size and number for three forb and two moss species. He also described thallome thickness and size and number of algal cells and hyphae in two lichen species.

In keeping with the paucity of information on the impact process, there are very few data on physiological responses to use. The only physiological responses examined at all are seed production, germination and dissemination, seedling establishment, and changes in the carbohydrate content of roots. However, Blom (1976, 1977), who studied the effects of trampling and soil compaction on the emergence and establishment of four *Plantago* species, has shown the direction such studies could take if we wanted a more detailed understanding of the physiological basis for observed impacts on vegetation.

Descriptions of soil changes, if anything, have been even more superficial. Most studies report loss of organic horizons, usually as changes in the percentage cover of litter and/or exposed mineral soil. A few also report the depth of organic horizons. Considerable attention has been given to soil compaction, with investigators usually reporting either penetration resistance or bulk density of the soil. While bulk density has the advantage of not being subject to moisture conditions, penetration resistance is a more sensitive indicator of impact. Others have measured consequences of compaction, particularly changes in total porosity, pore size, and infiltration rates. There are also some data on moisture content, organic matter content, and evidence of erosion. Soil properties for which very limited data exist include pH, nutrient content, texture, aggregate stability, and soil biota.

A few studies have attempted to model recreational effects on erosional processes utilizing the Universal Soil Loss Equation (Kuss and Morgan 1980, 1984; Morgan 1985). Such theoretical work has potential, but has yet to be translated into practical application.

As with the evolution of the recreational ecology discipline as a whole and the development of theoretical structure, research methods have not advanced greatly since Bates' (1935) early work on trampling effects on vegetation. Experimental work is receiving more emphasis but is not fundamentally different from earlier work. Similarly, more advanced techniques and equipment are available for measuring soil and vegetation properties but are seldom used.

RESEARCH RESULTS

Over the more than 50 years of research on recreational impacts, a considerable body of information has developed. Much of it is highly site-specific, but many general conclusions can be drawn from this work. I will begin by discussing descriptive studies of the effects of recreational activities on different types of recreation sites and the spatial and temporal patterns these impacts exhibit. Following these, I will examine the factors that influence type and magnitude of impact and studies that evaluate the effectiveness of management techniques. I will conclude with a discussion of work on monitoring and site rehabilitation techniques. Research in wilderness will be emphasized, but I will draw on information gleaned from studies undertaken in more developed settings. Other syntheses of research results include Speight (1973), Liddle (1975a), Satchell and Marren (1976), Wall and Wright (1977), Manning (1979), Hart (1982), Kuss and others (1985), Price (1985), and Cole (1985a).

Descriptive Studies of Recreational Impacts

The three primary activities by which recreationists alter wilderness soil and vegetation conditions are (1) trampling by humans and packstock, (2) the collection and burning of wood in campfires, and (3) the confinement and grazing of recreational stock.

Before turning to a detailed discussion of the impacts associated with these three activities, several unstudied sources of change should be mentioned. The first of

these is change caused by formal construction of campsites and trails. Campsite construction by managing agencies is rare but does occur. Generally this involves brush and tree removal and leveling of the ground surface. Trail construction, however, is common and probably has a greater effect on vegetation and soils than use of the trail by recreationists. During construction, vegetation is removed, soil is compacted, drainage is altered, and topography is rearranged.

Another unstudied source of change is the transportation of foreign substances into the wilderness. The propagules of exotic plant species are often brought unwittingly into the wilderness—on or in humans and packstock. Once inside they frequently establish themselves in disturbed areas. Garbage, soap, and waste water, particularly when scattered around campsites, can affect soil chemistry and biota; effects are likely to be highly localized, however. Finally, the effects of urinating on plants were investigated in Yosemite. This study concluded that although urine can lead to desiccation of plant tissues and increase the likelihood that a plant will be eaten, such effects are not pervasive enough to be significant (Holmes and Dobson 1976).

Effects of Trampling.—The most obvious effect of trampling is injury and destruction of ground-level vegetation. Injury results in reduced vigor and reproductive capacity in most species. At high levels of trampling or when fragile species are trampled, all plants may be eliminated. Some species may increase in abundance, however, and new species may be introduced. Increases are more likely to reflect reduced competition or a change in microhabitat than a positive response to trampling impact. For example, Pryor (1985) found that moderate levels of trampling increased the abundance of small *Juncus trifidus* plants, a species that germinates frequently on the bare and gravel surfaces that expand as a result of trampling. The final and most frequently documented results of trampling are loss of cover, reduction in stature, and shift in species composition.

The precise effects of trampling on plant morphology and physiology are poorly understood, as are the reasons some plants tolerate trampling better than others. Trampling reduces the area of individual leaves (Liddle 1975a). Goryshina (1983) demonstrated that this results more from inhibition of cell division than of cell elongation. Number of leaves and tillers, in grasses, is little affected by trampling (Liddle 1975a); however, number of leaves per shoot is reduced in orchids (Bratton 1985). Height is reduced and prostrate branching tends to increase as a result of frequent damage to terminal buds. Reduced height and leaf area decrease photosynthetic area; this depletes carbohydrate reserves (Hartley 1976) and can affect plant vigor. Physiological stress, such as reduction in photosynthetic area and carbohydrate reserves, along with mechanical damage to elevated buds, may explain reductions in flower density and seed production per flower (Liddle 1975a; Hartley 1976; Bratton 1985). However, few relevant studies have been conducted; this makes it difficult to evaluate whether these results are generally applicable or only apply to the species under study.

Trampling also compacts soils. Compaction reduces porosity, particularly the volume of macropores. This tends to reduce water-holding capacity in fine-textured soils and increase it in coarse-textured soils. Infiltration rates are universally reduced, leading to increased runoff and erosion potential. Other likely consequences that have only been studied in an agricultural context include oxygen shortages and changes in soil biota. Because these processes have never been studied in detail, we do not know with any surety what it is about compacted soils that makes vegetation reestablishment so difficult.

Many of these effects on soil are exacerbated by the abrasion and loss of organic horizons, a loss that becomes particularly pronounced following a reduction in vegetation cover. Loss of organic matter increases susceptibility to compaction and results in increased runoff. The soil biota is likely to be affected further, as is the germination capacity of species that prefer organic seedbeds. There is conflicting evidence regarding trampling's effect on organic matter incorporated within the mineral soil. Young and Gilmore (1976), Legg and Schneider (1977), Monti and Mackintosh (1979), Cole (1982b), and Marion (1984) found increases in soil organic matter content on campsites, while Dotzenko and others (1967), Dawson and others (1978), Rutherford and Scott (1979), and Stohlgren (1982) found decreases. This discrepancy does not appear to correlate with differences in vegetation, soil, climate, campsite age, amount of use, or measurement technique.

All of these changes are likely to affect germination, establishment, growth, and reproduction of plants. Compaction reduces the heterogeneity of soils and, therefore, the density of favorable germination sites (Harper and others 1965). Compaction increases the mechanical resistance of the soil to root penetration. This can reduce emergence of seedlings, although in some dry soils and for some species, this adverse impact is less important than the beneficial effect of increased water availability in compacted soils (Blom 1976). Once plants are established, low levels of compaction can lead to increased growth rates (Liddle 1975a). This probably reflects increased moisture again, and may not occur in soils where moisture is not limiting. At some level, compaction leads to oxygen shortage which, along with the mechanical resistance of the soil to penetration, inhibits root growth and, therefore, plant growth, vigor, and reproductive capacity. Effects on these processes are very poorly understood.

Impacts Associated with Campfires.—Ecologic impacts associated with campfires result from both the removal of wood, either dead or live, standing or on the ground, from large areas around campsites, and from the burning of this wood in campfires (Cole and Dalle-Molle 1982). Very little research has been conducted on this subject. The collection of firewood and associated trampling greatly enlarge the area affected by camping. In Great Smoky Mountains National Park, the area disturbed by firewood collection was typically more than nine times the size of the devegetated area around campsites. In this much larger area, number of live and dead trees, particularly those in smaller size classes, and woody

fuels were reduced (Bratton and others 1982). Shifts in understory species composition—presumably a result of trampling—were also evident in areas disturbed primarily by firewood collection (Saunders 1979). In Grand Canyon National Park, where campfires are prohibited, the areal extent of disturbance around campsites is remarkably small given the heavy use many of these sites receive (Cole 1985b).

The significance of firewood collection to the entire ecosystem can only be suggested from studies undertaken outside the recreational context. Such studies suggest that the most serious impacts are likely to occur when woody debris larger than about 3 inches in diameter is removed. Decaying wood of this size plays an important and irreplaceable role in the ecosystem—in water and nutrient conservation and as a substrate for biological activity (Harvey and others 1979). Collection of wood that can be broken by hand is likely to have relatively little effect (Cole and Dalle-Molle 1982).

The effects of campfires are particularly severe for the areas actually burned. In one experiment, a single intense campfire eliminated 90 percent of the organic matter in the upper inch of soil (Fenn and others 1976). Fires are also known to lead to losses of certain chemical elements (nitrogen, sulfur, and phosphorus, for example), increases in pH and many cations, and decreases in moisture-holding capacity, infiltration rates, and mycorrhizal populations in the soil (Cole and Dalle-Molle 1982). However, such changes have never been studied in a recreational context. Significance has never been assessed in terms of effects throughout the ecosystem or difficulty of rehabilitating fire sites. Usually campfire impacts are highly localized, but where fire sites move around, continually being rebuilt after being removed by rangers or other campers, a sizable area can be affected.

Generally, the whole subject of campfire-associated impacts and their management has been neglected and is poorly understood. This is particularly unfortunate given the energy currently expended on educating people in proper use of campfires. Managers are developing educational messages, and social researchers are experimenting with delivery systems for these messages. And yet, the bottom line is that we have not studied the problem and its potential solutions enough to know what the message should be and how it should be tailored to different environmental and use situations.

Effects of Confining and Grazing Recreational Stock.—Recreational stock trample vegetation and soil, as hikers do. They also cause some unique types of impact resulting from their need to graze (unless grazing is prohibited and all feed is carried in) and to be confined when not in use. The primary effect of confinement is localized severe trampling damage. Because a primary means of confinement is tying stock to trees, other serious problems are root exposure, as soil is eroded from around the base of trees, and damage of tree trunks from the abrasive action of rope. Where stock are tied to small trees, girdling can kill the trees. In the Bob Marshall Wilderness, campsites frequented by parties with packstock have an average of 25 trees with exposed roots (Cole 1983a). Although this type of damage has not been well studied, the problem, its cause, and its solution are obvious; consequently, this is not a high research priority.

In contrast, the effects of recreational grazing—also not well studied—are subtle and complex, as are the pros and cons of various potential solutions. Most of what we know about grazing impact comes from range management studies outside wilderness, usually dealing with animals other than horses and mules and with management objectives that place little importance on natural conditions. Moreover, in the few studies of range condition that have been conducted in wilderness, it has not been possible to isolate the effect of recreational grazing because it is superimposed on the effects of earlier or, in many cases, ongoing grazing by domestic livestock.

Sequoia/Kings Canyon National Parks are the only wildernesses where the effects of recreational stock on meadows have been assessed in detail. Over 40 years of research have been conducted, from early qualitative surveys of meadow conditions (such as Armstrong 1942) to recent controlled clipping experiments. These studies have provided a basic understanding of the nature of problems, trends, and relationships between meadow conditions and important environmental and use variables. The payoff to management is a proposed stock management plan that is efficient (meaning management objectives are met without the imposition of unnecessary restrictions) and thorough (DeBenedetti and Parsons 1983). Implementation of the plan is currently stalled due to objections from some of the recreational stock users.

Early meadow surveys in the Parks identified problems of reduced vegetation cover, rill, channel, and gully erosion, and invasion of meadows by lodgepole pine and other "weedy" species. Trend studies showed that actions taken to deal with these problems, including closing certain areas to grazing and limiting numbers of animals and lengths of stay, were generally successful. However, more subtle changes, not readily identifiable in the early qualitative surveys, were occurring, and management success varied from place to place and year to year. Consequently, more intensive quantitative research was conducted in the 1970's. This research provided a better understanding of annual fluctuations in the productivity of major plant associations and identified the response of each association to different levels of herbage removal. A predictive index of susceptibility to trampling under different moisture conditions was produced for each association. This allows managers to predict the consequences of alternative use prescriptions for individual forage areas, even accounting for differing hydrologic years. In addition to managing use effectively, the plan also incorporates a monitoring plan and designates a network of representative meadows for each major association to be protected from stock use (DeBenedetti and Parsons 1983). Other areas would do well to emulate such a research and management program rather than ignore the problem or institute arbitrary actions not based on an understanding of the resource, its condition, and its variability.

Impacts on Campsites.—Although affected by some of the same activities, impacts on trails and campsites—the two major focuses of impact and management—are sufficiently different to be discussed separately.

Impacts on campsites result from trampling by humans and, sometimes, by stock; the collection and burning of firewood; the confinement and grazing of stock; pollution with garbage, soap, and other substances; and thoughtless or malicious acts, such as hacking trees. Of these, trampling is the only unavoidable activity. The others are optional, and effects can be eliminated through education or prohibition of activities. Trampling impacts and their management are more subtle and complex and will be covered in more detail here.

Currently we have research data on campsites from 15 wilderness/backcountry areas: Olympic National Park (Schreiner and Moorhead 1979), Eagle Cap Wilderness (Cole 1981a, 1982b), Sequoia/Kings Canyon National Parks (Dykema 1971; Simon 1978; Parsons and DeBenedetti 1979; Stohlgren 1982), Bob Marshall Wilderness (Cole 1983a), Lee Metcalf Wilderness (Frissell 1973), Mission Mountains Tribal and Rattlesnake Wildernesses (Fichtler 1980; Cole and Fichtler 1983), Selway-Bitterroot Wilderness (Ranz 1979; Cole and Ranz 1983), Frank Church-River of No Return Wilderness (Coombs 1976), Dinosaur National Monument (Jerry 1977), Grand Canyon National Park (Carothers and Aitchison 1976; Cole 1985b), Boundary Waters Canoe Area (Frissell and Duncan 1965; McCool and others 1969; Merriam and others 1973; Marion 1984), Ozark National Scenic Riverways (Sutton 1976; Marnell and others 1978), the Adirondacks (Rechlin 1973), and Great Smoky Mountains National Park (Bratton and others 1978, 1982; Saunders 1979).

Half of these are descriptive studies of campsite conditions without relation to controls. They portray the extent and distribution of campsites in varying condition, but do not describe what has happened to the sites in terms of recreational impact. Of those that did estimate amount of impact, this amount is related to amount of use by Frissell and Duncan (1965), Sutton (1976), Coombs (1976), Simon (1978), Fichtler (1980), Cole (1982b, 1985b), Cole and Fichtler (1983), and Marion (1984); to type of use by Cole (1983a); to age of the campsite by Marion (1984); to environment by Dykema (1971), Sutton (1976), and Cole (1985b); and to time since the campsite was closed to use by Parsons and DeBenedetti (1979), Ranz (1979), Cole and Ranz (1983), and Stohlgren (1982).

These studies universally report the loss of vegetation cover and species change that generally result from trampling. Differences in the magnitude of change reported often reflect incomparable study methods as much as real differences. Species change and cover loss are most pronounced close to the center of campsites. Stohlgren (1982), for example, found that the core area of campsites just closed to use in Sequoia National Park had lost over 90 percent cover (in comparison to controls), compared to about 40 percent loss on less used parts of the site away from the core. Species richness and vegetation height were also reduced more in the core than on the fringes of the site. The sharpness of this intrasite disturbance gradient and the magnitude of differences vary with both amount of use and environment. In the Grand Canyon, no vegetation survives in the core of all but the most lightly used campsites; however, the area immediately adjacent to this barren core typically loses only about 12 percent cover (Cole 1985b). When intrasite variability is disregarded, reported measures of cover loss on the entire campsite range from 96 percent in Eagle Cap spruce forests in Oregon to less than 20 percent on montane grasslands in Montana's Bob Marshall (Cole 1981a, 1983a).

Shifts in species composition have been pronounced in all but two cases—the Grand Canyon and Rattlesnake Wilderness (Cole and Fichtler 1983; Cole 1985b). In these two cases, an index of floristic difference between campsites and controls had a mean of only 31 percent and 27 percent, respectively, within the range of variability expected in undisturbed vegetation. This compares with a mean index value as high as 88 percent in the Boundary Waters Canoe Area (Marion 1984). Species change is highest when resistance of the natural vegetation is low and there are many trampling-resistant invaders to take the place of the original occupants. Close to 20 percent of the species found on Boundary Waters campsites were nonnatives.

All studies—with the exception of the Grand Canyon, where no change in composition occurred (Cole 1985b)—have found that grasses and sedges increase in relative importance on campsites. Although they too are damaged by use, they survive more frequently than other growth forms. Low shrubs are generally susceptible to damage, as are tree seedlings and lichens. Loss of tree seedlings has been nearly complete on most campsites studied and is an especially serious problem for the long-term maintenance of forested campsites. Large shrubs are relatively resistant to damage, particularly if they are widely spaced and thorny, as they are on Grand Canyon sites (Cole 1985b). Forbs and mosses are highly variable in response; as a group they are neither highly resistant nor highly susceptible.

Established trees, because of their size, are generally little disturbed by trampling. Even where the practice of tying horses to trees exposes roots, tree mortality is seldom a problem, unless girdling occurs. Some tree species do appear to grow less rapidly in trampled areas (LaPage 1962; Brown and others 1977; James and others 1979). In shallow soils trampling can also increase water stress (Settergren and Cole 1970) and lead to increased windthrow (Frissell and Duncan 1965).

Although large enough to be spared most trampling damage, trees on campsites are frequently felled and used for tent poles, hitchrails, and firewood. On campsites in the Eagle Cap and the Bob Marshall, the median percentages of trees that had been felled were 28 (four trees per campsite) and 15 (15 trees). This loss is in addition to trees with exposed roots—32 percent (three trees) in the Eagle Cap and 54 percent (28 trees) in the Bob Marshall (Cole 1982b, 1983a). Root exposure is even more prevalent in the Boundary Waters Canoe Area, where shallow soils aggravate the problem (Marion

1984). Further damage is inflicted pointlessly by jackknife artists and ax-wielders. Although most trees survive such injuries, thin-barked trees, such as aspen and paper birch, are often killed (Hinds 1976; Marion 1984). Typically, few trees on campsites show no evidence of damage. Moreover, tree damage, in contrast to trampling damage, is cumulative and even longer lasting.

Loss of organic horizons follows loss of vegetation. Many campsites lose vegetation without losing litter, but the reverse is seldom the case (Cole 1982c). Loss of organic horizons occurs as a result of both trampling and increased runoff and erosion. As with vegetation loss, litter loss is greatest around the center of the campsite. Stohlgren (1982) found litter loss, by weight, to be over 90 percent of control values in the core and just over 60 percent on the fringes. Reported estimates of decrease in the thickness of organic horizons for entire campsites range from 45 to 66 percent (Frissell and Duncan 1965; McCool and others 1969; Cole 1982b, 1983a; Marion 1984). Litter loss exposes more mineral soil and rock. Amount of increase is highly variable among campsites both within and between areas. Typical increases have ranged from 6 percent in the Mission Mountains (Fichtler 1980) to 59 percent in the Grand Canyon (Cole 1985b). Differences relate both to how much use sites receive and the thickness of organic horizons on undisturbed sites (Cole and Fichtler 1983; Marion and Merriam 1985).

As was mentioned earlier, there are conflicting results concerning soil organic matter on campsites. On backcountry sites in the Eagle Cap Wilderness and Boundary Waters Canoe Area, Cole (1982b) and Marion (1984) found increases of 20 and 17 percent, respectively. On campsites in Sequoia National Park, in contrast, Stohlgren (1982) reported decreases of almost 80 percent in the core and almost 50 percent on the fringes. In neighboring Kings Canyon National Park, Simon (1978) found increases at one lake and decreases at another. No adequate explanation for such discrepancies exists. Such differences may be important to any site rehabilitation attempt, although rehabilitation appears to be difficult under conditions of both soil organic matter accumulation and depletion.

Experiments have shown that impacts on mineral soil are initiated even before vegetation cover starts to decline (Quinn and others 1980). Increases in penetration resistance and bulk density—both measures of compaction—have been identified in most campsite studies. Bulk density increases of 0.1, 0.1, 0.3, 0.3, and over 1.0 g/cm^3 were found by Simon (1978), Cole (1982b, 1985b), Marion (1984), and Stohlgren (1982), respectively. Both Cole (1985b) and Stohlgren (1982) found increases in bulk density outside the campsite core to not be statistically significant. Increases in penetration resistance—a more sensitive indicator of compaction—are statistically significant beyond the campsite core, suggesting that some compaction occurs even if increases in bulk density are not substantial enough to be accurately measured. On campsite cores, increases in penetration resistance of as much as 214 percent (Marion 1984) and 337 percent (Cole 1985b) have been recorded.

Changes in porosity—one of the more significant effects of compaction—have also been investigated. In a developed campground in Ontario, Monti and Mackintosh (1979) found a 60 percent loss of macropores. Along with frequent surface crusting (documented by increases in penetration resistance), loss of macropores reduces infiltration rates. Although reductions in infiltration on campsite cores were only about 30 percent in the Eagle Cap Wilderness, they typically exceeded 70 percent in the Bob Marshall Wilderness and Grand Canyon National Park (Cole 1982b, 1983a, 1985b). Reductions in initial infiltration rates were slightly less dramatic than reductions in saturated rates. Beyond the core of campsites in Grand Canyon National Park, infiltration rates were not significantly slower than on controls (Cole 1985b).

Where studied, soil moisture content has been lower on campsites than on controls. Reductions in soil moisture were more pronounced on campsites in Sequoia than Grand Canyon National Park (Stohlgren 1982; Cole 1985b). Core areas had reductions of 65 percent and 38 percent of control values, respectively. Reductions in fringe areas were 23 percent and 8 percent. In Kings Canyon National Park, Simon (1978) found a reduction of 19 percent of control values. Campsites in the Boundary Waters Canoe Area had only 7 percent less soil moisture than controls. Lower soil moisture should be the general case, although Liddle and Greig-Smith (1975) showed that in dry sand-dune soils experimental trampling could increase both soil water content and the amount of water available to plants. Blom (1976) has shown that under these same conditions (dry sand-dune soils) more seedlings of *Plantago major* emerged when soils were compacted. So, although soil compaction can be detrimental, there are at least some circumstances under which it can be advantageous.

Finally, changes in the pH and nutrient content of soils have been investigated by Cole (1982b) and Stohlgren (1982). In both cases pH was higher on campsites, but the other results are remarkable in their inconsistency. Cole found a doubling in the concentrations of both Mg and Ca on campsites, while Stohlgren found these elements to be reduced by factors of more than two. Cole found no statistically significant differences, between campsites and controls, in concentrations of NO_3, K, and total N, while Stohlgren found sizable reductions in all of these. Cole also found an increase in Na and no change in PO_4, while Stohlgren found decreases in P and NH_4. Results of similar analyses on developed sites generally corroborate Cole's results. Most nutrients increase while others are unaffected; none are greatly depleted (Young and Gilmore 1976; Rutherford and Scott 1979). Although results are confused, I hesitate to suggest a need for research until the significance of such changes is demonstrated. Suggested reasons for increases in nutrients include scattering of fire remnants, soap, and litter around the site, as well as reduced leaching due to decreased infiltration rates.

Erosion—aside from what occurs around the base of trees that have had stock tied to them—is surprisingly unimportant. In Great Smoky Mountains National Park,

for example, erosion is evident on less than 1 percent of the average area of intensive disturbance (Bratton and others 1978). Water velocities are low on most campsites because they are essentially flat, and soil does not detach readily from compacted surfaces. These factors inhibit erosion and compensate for the increase in erosion potential that results from reductions in vegetation cover, litter cover, and soil permeability on campsites. In most wildernesses, however, certain poorly located campsites likely will have serious erosion problems. Erosion problems are also unusually pronounced on campsites in the Boundary Waters Canoe Area, where soils are shallow and steep slopes from canoe landings to campsites are heavily trampled and eroded (Marion 1984).

Impacts on Trails.—It is more difficult to define when trail impacts become problems because the majority of change is purposeful change caused by trail construction and maintenance. Purposeful changes include opening up the tree and brush canopies in forest and shrublands; creating a barren, compacted trail tread that may alter drainage patterns; and producing a variety of new microhabitats—where slopes are flattened, rock faces are incised, and so on. Clearing vegetation increases light intensities and reduces competition for species capable of surviving along the trail. Shifts in species composition result from increases in trampling and grazing pressure, the dissemination of propagules of exotic plants, increases in nitrogen from urine and manure, increases in sunlight, and increases in moisture—less precipitation is intercepted by trees, fewer plants are losing water through evapotranspiration, and the compacted trail tread is shedding water along its sides.

The nature of shifts in species composition has been described, in wilderness situations, by Dale and Weaver (1974), Hartley (1976), Cole (1978), Stelmock and Dean (1979), and Teschner and others (1979). The most pronounced shifts are increases in exotic species and species with characteristics making them resistant to trampling, and decreases in shrubs and caulescent forbs. Meadow species often replace forest species (Dale and Weaver 1974). This reflects both a positive response to increased light along trails and the inability—according to general theory proposed by Grime (1979)—of plants adapted to the stresses of a low light environment to also adapt to a high disturbance environment. Specifically, shade-tolerant plants, in contrast to heliophytes, have more supportive and conductive tissue, greater leaf areas, and thinner cuticles, cell walls, and stems—morphological adaptations that make them susceptible to breakage (Cole 1979).

Where drainage disruptions cause water ponding, increases in moisture-loving plants and even aquatics occur. Where level, soil-covered trails are built across talus slopes, plants can spread into naturally inhospitable habitats. Numerous other construction effects on natural vegetation and soil conditions occur wherever trails cross the wilderness.

Because most of this is planned by management and accepted by the visitor, trail alteration becomes a serious problem only where it is unusually obtrusive (for example, where parallel ruts scar an alpine meadow) or where deterioration of the trail makes use difficult and requires the expenditure of large amounts of money and manpower for maintenance. While this is probably a realistic definition, it reflects the extent to which we use anthropocentric criteria to define impact problems. This anthropocentric bias is made even more clear by the fact that usually more money is spent dealing with trail problems than any other wilderness management problem.

Four important types of trail problems can be identified: (1) excessive erosion, (2) muddiness (with or without lateral spread), (3) multiple parallel trails, and (4) development of impromptu trails at attraction sites (for example, fishermen's trails around lakes or trailing and trampling damage near a waterfall). Erosion is a localized problem, although it does appear to be considerably more troublesome in the East, where trails are often steeper and use is heavier than in the West (Ketchledge and Leonard 1970; Bratton and others 1979). Two studies of erosion over an entire trail system (as opposed to examination of purposefully selected problem segments) found that deposition on trails actually exceeds erosion (Fish and others 1981; Cole 1983b). Material does move about, entering and leaving the system, but accumulation is greater than depletion.

As far as ease of use is concerned, the trail-system-wide lack of erosion is irrelevant. The problems are those stretches where erosion is pronounced, particularly where trails develop an uneven rocky tread or are deep and narrow. Interestingly, wide and deep trails (where erosion loss is greatest) are less of a problem to users than narrow and deep trails. Although trampling can cause erosion of some trails, its principal effect is to make the trail surface more susceptible to erosion by churning up the soil, reducing infiltration rates, and removing vegetation. The primary agent of erosion is running water from streams, snowmelt, intercepted springs, and even intense precipitation (Root and Knapik 1972). Erosion is primarily a problem where trails channel water and water is not diverted off the tread.

Erosion of wilderness trails has been studied by Ketchledge and Leonard (1970), Dale and Weaver (1974), Helgath (1975), Bratton and others (1979), Teschner and others (1979), Summer (1980), Fish and others (1981), and Cole (1983b). Most of these researchers studied the relationship between trail deterioration and use and environmental variables, a topic that I will discuss later. Dale and Weaver (1974), Bratton and others (1979), and Cole (1983b) also measured trail width, depth, and erosion problems, extremely site-specific data. Trails in Great Smoky Mountains National Park were generally wider and less deep than those examined in the Northern Rockies. In terms of annual change—again a very site-specific measure—Ketchledge and Leonard (1970) recorded an increase in trail width and depth of 1 inch per year in the Adirondacks. Summer (1980), working in Rocky Mountain National Park, found annual increases in depth of 0.4 to 5 inches (mean of 2 inches) and annual increases in width of 0 to 59 inches (mean of 5 inches). On two highly eroded segments in the Selway-Bitterroot Wilderness, Cole (1983b) recorded annual cross-sectional area losses of 30 and 56 in^2. Such figures represent the worst examples and are highly variable at all scales from a few feet to nationwide.

Muddiness can be a significant problem. In the Bob Marshall, where trails are often calf-deep in mud, complaints about damaged trails increased sixfold between 1970 and 1982 (Lucas 1985). Unwilling to walk through the quagmire, hikers and stock skirt the problem, widening the trail and the quagmire greatly. In some cases, mud is a temporary problem caused by snowmelt or by intense rainfall on trails that have been churned to dust. Mud can also be a season-long problem in soils with high or perched water tables (Helgath 1975). About 9 percent of the maintained trail system in Great Smoky Mountains National Park was muddy (defined as having a soil surface that moved when wet) (Bratton and others 1979). Surveying 17 miles of trail in the Selway-Bitterroot, Cole (1983b) recorded mud at 17 percent of the observation points, but only 1 percent of the trail was muddy enough to make travel difficult. The sporadic problem segments—28 in all—averaged 56 inches wide, almost 2.5 times the Forest Service maximum tread width standard of 24 inches.

Multiple parallel trails are a troublesome problem in meadows, particularly at high elevations. Here the problem is primarily esthetic, as such stretches are not difficult for hikers or stock to negotiate if they walk on one of the less deeply incised treads. This aggravates the multiple trailing problem further and leads to an increase in both the number of treads and the width of disturbance. From my observations, total width and intensity of surface deterioration never reach the extremes they do with muddiness problems. Multiple trailing has not been specifically studied in the United States wilderness. However, Price (1981) examined the problem in alpine meadows adjacent to the Sunshine ski area in Banff National Park, AB, and Palmer (1979) described some experiments with various means of rehabilitating multiple trails in Yosemite National Park.

The final problem, impromptu trail development, is a catchall category for recreational impacts outside campsites, designated trails, and grazing areas. The most frequent impacts are "fishermen's trails" around lakes and along streams and trampling damage at scenic attractions, such as waterfalls and other scenic viewpoints. This situation is the one most analogous to the random trampling generally studied by British recreational ecologists. Although seldom mentioned in more than casual observations, this type of impact is probably most similar to what happens on campsites. Vegetation is lost; what survives is floristically, morphologically, and physiologically distinctive; organic horizons are removed; and soils are physically, biologically, and probably chemically altered.

Managers' Perceptions of Problems

Two studies have attempted to assess the prevalence and significance of impact problems by querying wilderness managers about various problems that make it difficult for them to achieve management objectives. In a survey of managers of selected wildernesses, 80 percent of the managers that responded to an open-ended question about important problems mentioned trail and campsite deterioration. The only other frequently mentioned recreation-related problem was user conflict (Godin and Leonard 1979). The conclusion that trail and campsite deterioration is, in the opinion of managers, the most prevalent recreation-related problem in wilderness was corroborated in a more extensive survey of managers of all units in the National Wilderness Preservation System (Washburne and Cole 1983). Trail deterioration and campsite deterioration were considered to be a problem by 76 and 72 percent of the managers, respectively. This compared with perceived problem frequencies of 51 percent for crowding, 36 percent for impacts on wildlife, and 22 percent for water pollution.

This finding that campsite and trail deterioration is the most frequent recreation problem in wildernesses, at least in the opinion of managers, suggests that ecological problems occur at lower use levels than social problems. Reviewing recreation problems in England, Munton (1972) also concluded that "the thresholds of the semi-natural biological system are exceeded . . . before the psychological threshold resulting from overcrowding."

In addition to being a problem in more wildernesses, campsite and trail deterioration are also the most widespread problems within individual areas. When asked if problems occurred in "a few places" or in "many places," the number of wildernesses (out of 152) with problems in many places were 51 for campsite deterioration, 39 for trail deterioration, 19 for crowding, 9 for wildlife disturbance, and 3 for water pollution (Washburne and Cole 1983).

Beyond assessing the prevalence of problems, one would also like to assess the importance of problems. This, however, is where the insufficient research base becomes readily apparent. In contrast to considerable research on the extent to which crowding detracts from visitor satisfaction (an important management objective in wilderness), there has been little attempt to assess the importance of vegetation and soil deterioration in terms of not maintaining natural conditions (the primary management objective in many people's opinion). We desperately need a better understanding of the significance of these prevalent ecological impacts on trails and campsites.

Spatial Distribution of Impact

One component to be addressed when considering the significance of impacts is the areal extent of impact. On this basis, one might conclude that impacts are not highly significant. Recreational use is highly concentrated along a few major trails and at a few popular destinations. This leaves the vast majority of wilderness essentially unvisited and therefore undisturbed by recreational use. In the Adirondacks, Rechlin (1973) estimated that only 0.01 percent of the area had been disturbed by camping. In the Great Smoky Mountains, where camping is allowed only on designated sites, a conservative estimate of camping disturbance was 0.06 percent of the backcountry (Bratton and others 1978). In two relatively popular drainages in the Eagle Cap Wilderness, where camping is allowed almost anywhere, Cole (1981a) estimated 0.2 percent was disturbed by

camping. Finally, 1.3 percent of a very popular lake basin in the Eagle Cap had been disturbed by camping (Cole 1982c). Although this percentage is still small, it is concentrated in the places where visitors spend most of their time—so evidence of human impact is omnipresent—and certain types of environments (flat, rock- and brush-free locations) may all be disturbed by camping.

Other areas have been disturbed by trails and grazing. Trail disturbance varies greatly between areas. Results of a survey of wilderness managers (Washburne and Cole 1983) indicate that the highest trail densities are in the Sawtooth and Joyce Kilmer-Slickrock Wildernesses. Assuming a 9-foot-wide swath of disturbance, about 0.7 percent of these wildernesses has been disturbed along designated trails. Over an entire wilderness, trails and campsites are unlikely to disturb more than 1 percent of the area. Locally, however, they could disturb a much higher percentage of popular lake basins and lakeshore areas.

More significant, in many places, is the area disturbed by grazing. In part of the Eagle Cap Wilderness, this amounted to about 1.3 percent of the area—almost three times the area of trails and campsites (Cole 1981a). However, more important than areal extent is the fact that grazing often occurs on relatively rare ecosystem types. In some places all representative examples of some meadow types may be disturbed by grazing. This, without question, represents a serious problem and a change that is essentially irreversible. The frequency of such situations has never been assessed, but it argues for the wisdom of a policy, such as that proposed for Sequoia/Kings Canyon National Parks, prohibiting grazing of representative examples of most meadow types. The near-complete lack of research on grazing impacts and their management in wilderness is a serious research gap.

Concentration of use on a small proportion of the wilderness can and has been considered both a bad and a good thing. Some have argued that most impact problems result from excessive concentration of use (Stanley and others 1979). In their survey of managers, Washburne and Cole (1983) reported that the most frequent response to an open-ended query about management's most significant problem was impact as a result of concentrated use. Others suggest that this tendency for use to be concentrated is what has kept wilderness resources as undisturbed as they currently are (Cole and Fichtler 1983). Clearly, managers should actively manage spatial patterns of use and impact. There may be situations where excessive impact at concentrated use sites should be reduced through use dispersal; there are also likely to be situations where undisturbed areas should be preserved through maintenance of existing patterns of use concentration.

The major threats to the concentration of impact are cross-country travel and the proliferation of campsites in destination areas. Neither have been examined in much detail. Cross-country travel, if use is frequent enough, can lead to the development of undesired impromptu trails. Where this occurs, the only management options are either to restrict use or to designate official trails and confine impact to those trails. The campsite proliferation problem was documented by Cole (1982c) in the Eagle Cap Wilderness, where 221 campsites were found around two subalpine lakes. Where use levels are high, campsite proliferation can only be avoided by confining use—either through education or regulation—to a small number of established sites. Where use levels are low, both highly impacted sites and site proliferation can be avoided through use dispersal and promotion of minimum impact camping techniques. Management of both the impromptu trail problem and the campsite proliferation problem would profit from more research on the relationship between use and impact discussed below. Such research could identify, for major ecosystem types, use thresholds beyond which trail and campsite problems are likely to develop.

On a smaller scale there are distinctive impact patterns on individual campsites. We have already described differences in amount of impact between the campsite core and fringes of the site. Often this concept of radial impact, with impact decreasing with distance from the campsite center, breaks down. Campsites may be linear or L-shaped, and they often include undisturbed "islands" and disturbed "satellite" sites. McEwen and Tocher (1976) proposed recognizing three zones for developed campsites: "(1) impact zone, the corridors of heavy use between and around site facilities; (2) intersite zone, the relatively undisturbed areas between the corridors of heavy use; and (3) buffer zone, the rarely disturbed areas at the border of the site." They prescribed different management strategies for each zone, emphasizing concentrated use on a small impact zone, creating intersite zones, and preserving the buffer zone.

In wilderness, these impact patterns are less pronounced because unstructured campsites have a more diffuse zonation (Hart 1982). In heavily used areas, however, facilities such as fire grates and toilets are not uncommon, and they tend to structure zonation patterns. In 1980, 19 percent of wildernesses had open-pit toilets, 15 percent had enclosed outhouses, 12 percent had shelters, 10 percent had constructed fireplaces, 8 percent had tables, and 7 percent provided a potable water supply (Washburne and Cole 1983). Clearly, impact could be reduced by channeling use between such facilities through careful design during construction and maintenance. Policies regarding fire rings—whether they are broken up or left—will also affect impact patterns; impacts are likely to be more extensive where fire rings are frequently broken up and rebuilt in different parts of the site (Cole and Dalle-Molle 1982). There is also a strong tendency for campsites to expand in area over time (Merriam and others 1973). Amount of expansion is likely to be greatest in open vegetation types and in places where party size limits are high and where party members tend to seek privacy from each other (for example, on outfitted trips made up of numerous unrelated individuals or groups). It should be possible to confine expansion, channel use to selected satellite sites where necessary, and protect most of the buffer zone from indiscriminate expansion. Despite increased expenditures by managers on site maintenance, no research

evaluating existing efforts or suggesting improved techniques has been conducted. The benefit/cost ratio of such work would be high.

Considerable effort is also going into rehabilitating campsites, usually after permanently closing them. Research on this subject will be described more fully later. However, closures are sometimes temporary and in some cases (for example, the Boundary Waters Canoe Area and Eagle Cap Wilderness) some rehabilitation is attempted without curtailing use. A particularly important goal of such efforts is to get some tree reproduction on sites where it has been eliminated by trampling. Designing impact zones and protected intersite "islands" is critical to successfully rehabilitating any site that will be used again.

Trails have a sharp disturbance gradient perpendicular to the trail. The central trail tread is usually devoid of vegetation and organic matter and is highly compacted. Disturbed strips, on either side, are usually vegetated, but vegetation stature is short, cover is often low, and composition is different from adjacent undisturbed vegetation. If in a forested zone, trees are absent along the tread and disturbed zones. Lack of an overstory affects microclimate along the trail. The width of these zones is quite variable, but from the perspective of the entire wilderness, they are always narrow. The combined width of tread and disturbed zones is typically about 9 feet but can be much wider, particularly in meadows and where the trail is muddy.

The lateral expansion of trails can be controlled. Stock, in particular, tend to walk on the downslope side of trails. This breaks down the outer edge of the trail so that more soil must be brought in to rebuild the trail. The result is a wide trail, a much wider zone of disturbance, and an ongoing maintenance problem (Whitson 1974). Placing boulders on the outside of the trail can force stock and hikers to walk on the inside of the trail. Other techniques, such as avoiding excessive trail brushing, locating the trail in rough terrain (Bayfield 1973), and bridging wet areas can be used to limit lateral expansion.

Temporal Aspects of Impact

The few studies that have examined rate of deterioration on newly opened sites show that impacts occur very rapidly, even with moderate use, during a break-in period that seldom lasts more than several years (LaPage 1967; Merriam and others 1973; Legg and Schneider 1977). On new campsites in the Selway-Bitterroot Wilderness, vegetation loss approximated that on older campsites within 5 years. Loss of organic matter and resulting exposure of mineral soil occurred more slowly, but after 8 years was as pronounced as on older sites (Cole and Ranz 1983). On more heavily used sites, these changes can occur more rapidly. Merriam and others (1973) recorded near maximum levels of soil compaction after just 2 years' use on Boundary Waters Canoe Area sites. LaPage (1967), working on developed campsites, found that vegetation cover reached minimum levels after the first year of use. Where use levels are low, however, one study documented very little impact caused by camping (Leonard and others 1983).

After the break-in period comes a period of dynamic equilibrium (Hart 1982) in which seasonal and annual fluctuations predominate, in contrast to the unidirectional deterioration that occurs during the break-in period. On developed sites, Echelberger (1971) and Magill (1970) found little deterioration and some improvement over 5 years of use on long-established campsites. In the Boundary Waters Canoe Area (Merriam and Smith 1975; Merriam and Peterson 1983), the most pronounced change over time on sites at least 5 years old was an increase in campsite size. There also may be increases in tree damage, which is cumulative, in contrast to trampling damage, which after a few years should fluctuate around an equilibrium level (Hart 1982). Without management intervention, the dynamic equilibrium period will be followed, on forested sites, by a dying forest; sites must either become nonforested or be abandoned. The time it takes to reach this deteriorated state is determined by the longevity of tree species; it will usually be measured in hundreds of years, so we have few examples. However, the susceptibility of aspen to canker diseases following mechanical injury from recreationists makes the life span of developed campsites in aspen about 30 years (Hinds 1976). Maroon Lake Campground, an aspen campground in Colorado, is one of the first documented examples of a campground beyond the dynamic equilibrium phase (Johnson and Hinds 1977).

The first study to seriously question the dynamic equilibrium concept was Marion's (1984) recent examination of conditions on campsites in the Boundary Waters Canoe Area. He examined differences in amount of impact on campsites in three age classes: 5 to 10 years old, 11 to 13 years old, and more than 13 years old. There was little difference between the 5- to 10-year-old and 11- to 13-year-old sites, but the more-than-13-year-old sites had more root exposure and tree damage; they also were larger, and had experienced greater increases in bulk density and shifts in species composition. The larger area and greater root exposure and tree damage were as expected; however, the other changes challenge the notion of equilibrium. Differences in amount of impact are not pronounced; after statistically controlling differences in amount of use, an overall index of impact showed that 5- to 10-year-old sites had experienced 86 percent as much change as the over-13-year-old sites. However, this does suggest that trampling damage may increase slightly over time. Unfortunately, in addition to being older, these sites are also unique in their use history and location. They were developed by campers, prior to restrictions on party size and camping techniques, in prime locations. The younger sites were developed by the Forest Service, with concern for design and durable locations, and did not go through the "frontier lifestyle" phase the older sites did. It is impossible to separate these factors from campsite age and conclude that today's young sites will, over time, become like today's old sites. This is a good illustration of how lack of longitudinal studies forces reliance on cross-sectional

studies that cannot, by themselves, provide definitive answers to questions such as how impacts change over time. For more detail on campsite changes over time, refer to the paper by Cole and Marion presented elsewhere at this conference.

Two factors contribute to the tendency for trampling damage to equilibrate. The first is that many types of impact reach a maximum limit. For example, bulk density will eventually reach a limit above which much heavier loads would have to be applied to cause an increase. The second factor is the existence of homeostatic controls or negative feedback loops. A pattern of impact and recovery, such as erosion of leaf litter every summer and accumulation of leaf litter every fall, tends to keep litter cover fairly constant. In a few cases, the impacts of recreation use actually decrease the likelihood of further deterioration. On trails, and to a lesser extent on campsites, soil compaction following trampling can stabilize the soil surface, making it less prone to further erosion (Malin and Parker 1976). It is still a highly altered environment, inhospitable for vegetation, but less likely to erode than it was in the phase between initiation of development and the formation of a compacted surface.

In a similar manner, trampling disturbance may promote the invasion of trampling-tolerant species. On newly opened developed campsites, LaPage (1967) documented an initial rapid loss of vegetation cover. After this initial drastic loss, however, vegetation cover during the second, third, and fourth years of use actually increased as trampling-resistant, often exotic species, invaded the site. The resultant ground cover, being relatively tolerant of recreation use, resists further cover loss. These homeostatic controls are much less effective in environments where recovery processes are extremely slow or where there are few "weedy" invader species. Alpine ecosystems are deficient on both of these counts and, therefore, deterioration can be unusually severe once use exceeds tolerance thresholds.

Studies of recovery rates on recreation sites are almost as rare as studies of deterioration over time. Longitudinal studies of 3 years' recovery on campsites were done in Sequoia National Park (Stohlgren 1982) and the Selway-Bitterroot Wilderness (Cole and Ranz 1983). Cross-sectional studies in the same areas estimated recovery over 15 years (Parsons and DeBenedetti 1979) and 5 years (Ranz 1979). Willard and Marr (1971) investigated recovery of tundra over a 2-year period near parking areas in Rocky Mountain National Park. Others have investigated the effectiveness of cultural means of increasing recovery rates (a topic discussed below) and have followed recovery after artificial trampling experiments for periods up to 8 years.

Recovery periods are universally long, but they have only been examined in harsh environments where low resilience would be expected. Assuming a linear recovery rate in the future, a cross-sectional study of 5 years' recovery allowed Ranz (1979) to predict recovery of predisturbance vegetation cover in 16 years. However, a followup study indicated recovery rates were not constant or linear functions (Cole and Ranz 1983). Moreover, core areas of campsites require much longer recovery periods than fringe areas of campsites. Stohlgren (1982) estimated recovery periods for vegetation cover—again assuming linear rates—of 56 years in the core and only 5 years in the periphery. Recovery periods for bulk density were 36 years in the core and 11 years in fringe areas. In a cross-sectional study in the Boundary Waters Canoe Area, estimated recovery periods were 20 years for vegetation cover, 50 to 60 years for a return to normal species composition, and 30 to 40 years for bulk density (Marion 1984). After 15 years without use, litter accumulation and soil penetration resistance on campsites in Kings Canyon National Park had reached inferred predisturbance levels, but fuel accumulation was still low and tree mutilations, social trails, and vegetation deterioration were still evident (Parsons and DeBenedetti 1979).

Two major implications of rapid deterioration and slow recovery are that impacts are inevitable with use and that they are unlikely to be managed efficiently through adoption of a rest-rotation system. Rest-rotation, an often-suggested management practice in which sites are periodically closed and then reopened after recovery, would lead to many closed sites for each open site, as long as recovery periods are longer than deterioration periods. Since all research shows recovery periods to be many times greater, rotation appears to be generally impractical.

There is some indication that recovery can be relatively rapid if use only occurs for 1 year (Willard and Marr 1971 and several experimental trampling studies). Some wildernesses, such as Shenandoah National Park, where resilience appears to be high, have been trying variations of rest-rotation systems. Research evaluating the relationship between duration of impact period and recovery rates in more resilient ecosystems and the success of management systems such as the one at Shenandoah would expand our understanding of how recreation sites change over time.

On trails, some segments are relatively stable while others deteriorate rapidly. Generally, most change occurs during initial construction of the trail. Subsequent "problems," such as erosion, probably also occur rapidly. Old, traditional trails in Great Britain, for example, do not seem to be getting wider with age (Bayfield 1985). Recovery rates, unless assisted, are likely to be even more lengthy than those on campsites. In many cases, trail erosion is likely to continue even after all use has been curtailed. All one has to do is look at the slow recovery of trails abandoned after rerouting to see this.

Recovery rates on trails are highly variable, however. Experimentally trampled trails in the southern Appalachians were almost completely revegetated after just 1 year (Studlar 1983), while vegetation cover was only 24 percent of that on controls after 6 years of recovery in dry alpine meadows in Glacier National Park (Hartley 1976). Rates are highly variable even within the same general area (Leonard and others 1985). For example, 5 years after being experimentally trampled by horses, vegetation cover of a grassland (*Festuca-Poa*) was 100 percent of normal; cover in a forest (*Pinus-Vaccinium*) was only 26 percent of normal (Weaver and

others 1979). In addition to faster recovery in nonforested areas, observations suggest that wet places revegetate more rapidly than dry places. Natural infilling of severely eroded trails may never occur, except in depositional locations. Extensive rehabilitation work is often the only feasible means of bringing about recovery.

Factors that Influence Amount of Impact

Perhaps the greatest increase in understanding over the past 10 to 15 years has come from investigations of factors that influence amount of impact. This probably reflects the fact that such studies, while requiring more sophisticated research designs and analyses than descriptive surveys, can still be completed over a short period of time using cross-sectional techniques. Understanding the factors that influence impact is of paramount importance because managers can manipulate these factors to control amount and type of impact. This subject is the ecological analog to the so-called carrying capacity research by social scientists in which factors affecting crowding and visitor satisfaction have been studied.

The principal factors that have been identified are (1) amount and frequency of use, (2) type and behavior of users, (3) season and time of use, and (4) environmental conditions where recreation use occurs. While these are the factors that determine intensity of impact at any point of use, the areal extent of impacts is also affected by the spatial distribution of use, particularly its level of channelization. Although seldom the direct subject of research, it is clear that, everything else being equal, greater concentration of use leads to disturbance of less of the wilderness. When developing management strategies, both the factors that influence intensity of impact and those that influence level of use concentration need to be considered.

Amount and Frequency of Use.—Amount of use, strictly defined, should refer to the total number of people that have ever used a site or trail. However, the effect of a given number of users is likely to be modified by the number of years over which that use is spread. One would intuitively expect that, for a given number of users, spreading use over more years would cause less impact because this offers more opportunity for recovery. This hypothesis has never been adequately tested, however. If true, it would justify the tendency to use amount of use per year—a frequency measure—instead of total use as an independent variable.

Even when using measures of amount of use per year, there is some question about the importance of how that use is distributed over the year. Here some very limited data from trampling experiments suggest that, for a given amount of use, the distribution of that use over the year is a relatively unimportant factor (Cole 1985c). For example, the effect of 50 parties of two (100 total visitors) should be about the same as two parties of 50. While this seems reasonable on trails, it is not a reasonable assumption on campsites, where party size makes a difference, particularly to campsite size. Generally, recognizing considerable ignorance of the importance of frequency, studies of trail impact should use measures of total visitors per year (hopefully comparing trails of about the same age and that have not experienced major recent increases or decreases in use). In campsite studies, party-nights per year is probably as valid a measure as visitor-nights per year; both are probably important. In reality most studies have had to rely on ordinal use estimates of occupancy rates because these are all that are available. However, each of these measures has different implications that should be kept in mind.

Conventional wisdom has often held that amount of use is the most important factor influencing amount of impact. Such thinking has been supported by calling deteriorated sites "overused" and by proposing that solutions can be found by prescribing a "carrying capacity." Research shows that such thinking is oversimplified at best, and erroneous at worst. The importance of amount of use varies between environments, between activities, with impact parameter, and with the range of use levels being examined. In addition, effects differ depending on whether concern is with rate, intensity, or areal extent of change.

Research on the relationship between use and impact began in the early 1960's, with Frissell and Duncan's (1965) cross-sectional analysis of Boundary Waters Canoe Area campsites and Wagar's (1964) experimental trampling study in a recreation area in Michigan. Both studies examined the effect of different use levels on loss of vegetation cover. Frissell and Duncan (1965) found that the most lightly used campsites (0 to 30 nights per year) had lost 80 percent of their inferred original cover, while heavy use sites (60 to 90 nights per year) had lost only 7 percent more—87 percent. Wagar (1964) also found that although impact does increase as use increases, small amounts of use cause substantial amounts of impact. This relationship between amount of use and loss of vegetation is shown in figure 4. The curves are asymptotic, rather than linear. They have a single inflection point that separates the rapidly rising segment of each curve from the segment where increase in amount of impact is small.

The shape of this curve and the location of the inflection point have important implications for management. Attempts to limit vegetation damage by keeping use levels low will only be effective where use levels can be kept substantially below the use thresholds that correspond to the inflection points—those use thresholds are points X(a) and X(b) on the X axis. This may be impossible to do in portions of wildernesses that receive even moderate levels of use. Several studies in subalpine forests suggest that use levels of only five nights per year exceed these threshold levels (Cole and Fichtler 1983). In such places, concentration of use on a small number of sites appears to be the most appropriate strategy for minimizing vegetation loss.

Most studies have examined only sites with use levels beyond those that correspond to the inflection points on the curve. Consequently cover differences are not substantial and, generally, not statistically significant. One exception is Coombs (1976), who found that very lightly

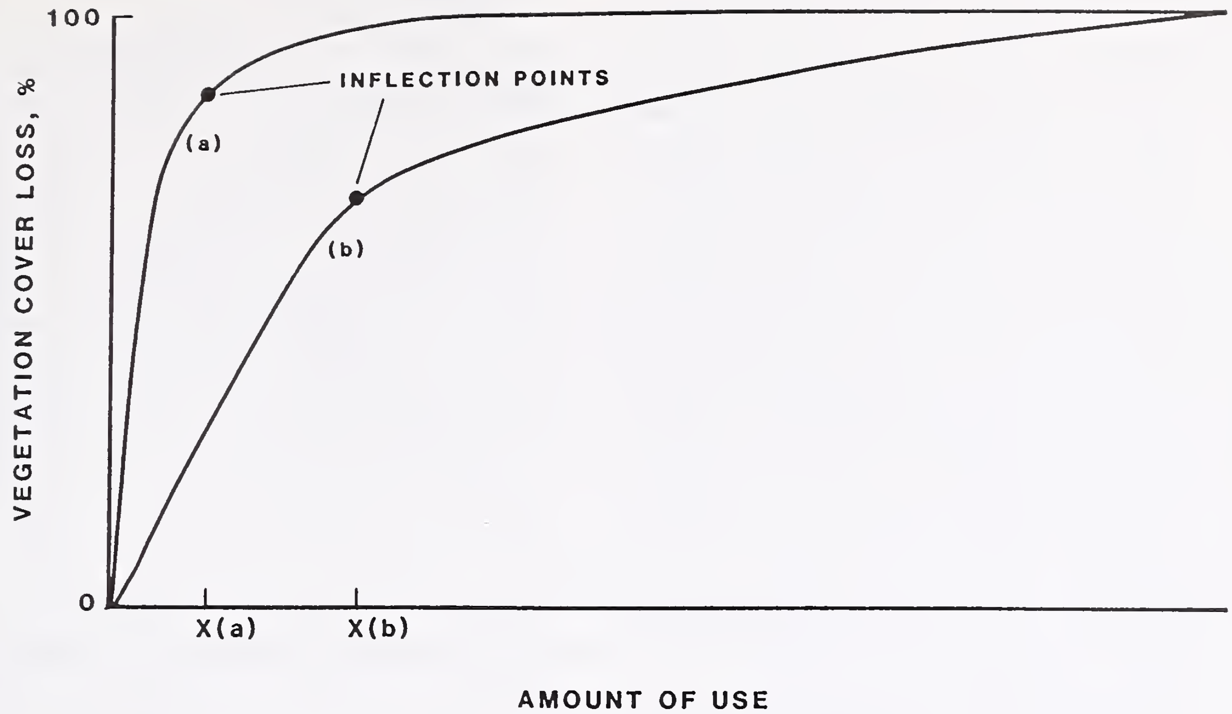

Figure 4.—The general relationship between amount of use and loss of vegetation cover for (a) a fragile vegetation type and (b) a more resistant type.

used sites, in what is now the Frank Church-River of No Return Wilderness in Idaho, had experienced less than 40 percent as much vegetation loss as heavily used sites.

Below use thresholds, even slight reductions in use can reduce vegetation loss substantially. This suggests a real opportunity to minimize impact in remote, lightly used places. In portions of wilderness where use levels can be kept well below these thresholds, it appears most appropriate to spread people out over a very large number of sites so that use levels are as low as possible. For this to work, visitors must be taught to use unused rather than lightly used sites, to practice low-impact camping, and to try to eliminate all traces of their stay when they move on.

Identification of inflection points and use thresholds offers tremendous potential for management because they can be used to choose between the opposing strategies of concentration and dispersal. Virtually every wilderness in the country could profit from employing both of these strategies in some part of their area.

Curvilinearity and the location of inflection points vary with differences in type of use and differences in environmental durability, however. In figure 4, curve (a) depicts the use/impact relationship for a quite fragile vegetation type, while curve (b) depicts the same relationship for a more durable type. Curve (b) is not as strongly curvilinear, and the use threshold associated with the inflection point—X(b)—comes at a higher level of use. If managers can get people to camp in type (b) rather than type (a), about twice as much use can be absorbed before the need to adopt a concentration strategy arises.

In one of the few studies undertaken on resistant vegetation types, Dunn and others (1980) examined developed campgrounds in the Atlantic Coastal Flatwoods region of South Carolina. They found no significant loss of vegetation cover except on heavy use sites. As in most other studies, inadequate measures of use make it impossible to establish use thresholds for these South Carolina campsites. More research, employing better use estimates and controlled experiments, could enable us to establish use thresholds for important environments across the country.

Hylgaard and Liddle (1981) hypothesized a rather different shape to the use/impact curve. They fitted cover loss, following experimental trampling, to a logistic equation. Logistic curves have three segments separated by two inflection points. At the very lowest use levels differences in amount of use have little effect on cover loss; vegetation can tolerate a certain amount of use before plants are killed. Above the first inflection point, cover loss increases rapidly with increasing use until the second inflection point is reached; beyond this point increases in use have less and less effect on vegetation cover. While such a model is intuitively appealing, there are few data to evaluate it.

Data from an experimental trampling study being conducted in Montana are presented in figure 5. Data are for two vegetation types that had been trampled for 2 successive years. A pass is a one-way walk down a trampling lane. The use/impact relationship for the spruce forest exhibits the highly curvilinear form of a fragile vegetation type—with an inflection point at around 200 passes per year. That corresponds to about 2 nights of camping use per year by an average party (Cole 1985c). In this forest, once use levels reach 2 nights per year, further increases in use cause little additional vegetation loss. Unless use levels can be kept at or below 1 night per year, it seems most appropriate to concentrate use on a few of these forested sites.

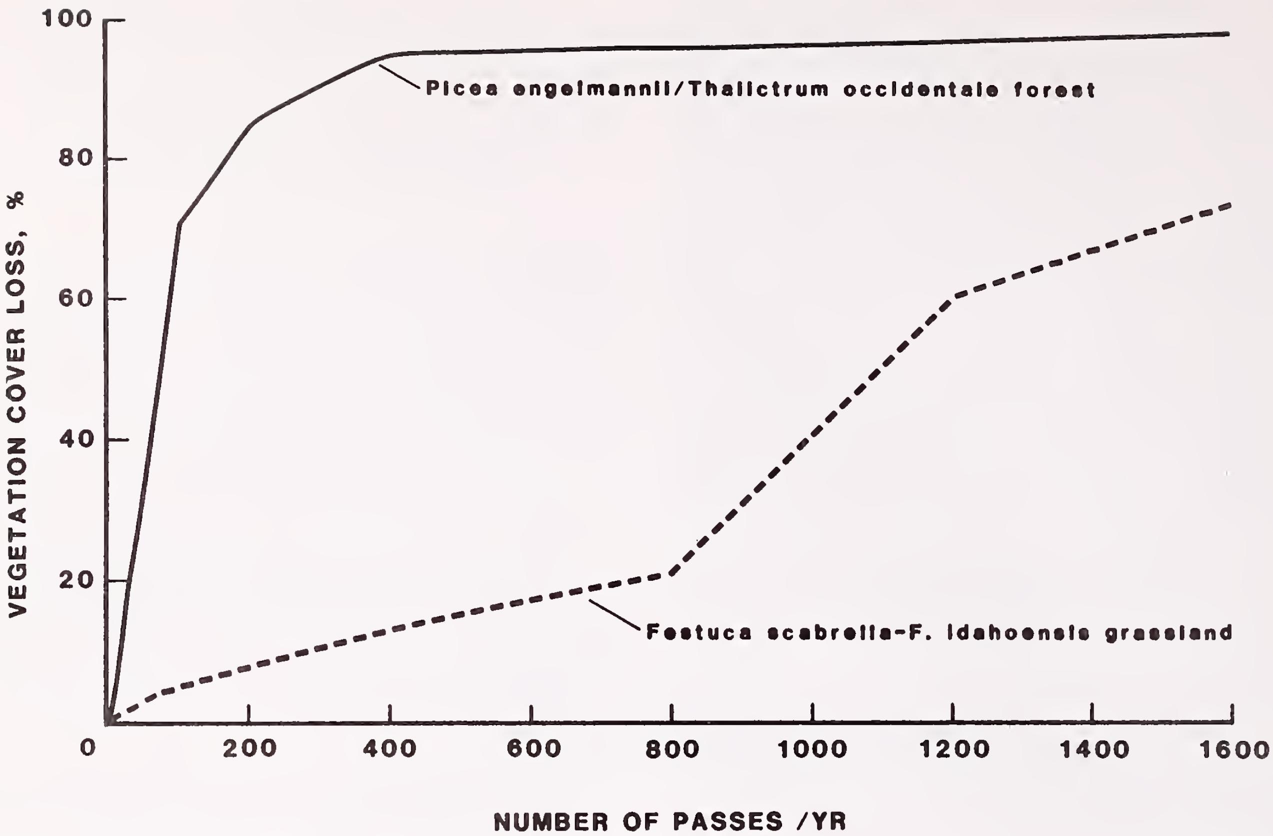

Figure 5.—The relationship between number of passes per year and vegetation loss (as a percent of original vegetation cover, adjusted for changes on controls) for two vegetation types in western Montana. Trampling was applied for two seasons.

The grassland, however, exhibits the form of a logistic curve with two inflection points. Below 800 passes per year, further reductions in use have little effect. In other words, there is some initial resistance to vegetation loss before further increases in use cause a substantial loss of vegetation. Apparently, only the most resistant vegetation types have this form.

Another complication to our original simple model comes from the fact that the shape of the curve varies with the type of impact being studied. Figure 6 shows some data from a recent study of campsites in the Boundary Waters Canoe Area (Marion 1984). For each parameter, amount of change on low-, moderate-, and high-use sites has been expressed as a percentage of change on the high-use site. Degree of curvilinearity and use thresholds differ between parameters. Just as vegetation types vary in their susceptibility to any type of impact, the susceptibility of a site to different types of impact is also variable. Those parameters, like vegetation cover, for which a highly curvilinear relationship exists, include bulk density, penetration resistance, macropore space, infiltration rate, changes in soil chemistry, loss of tree seedlings, and tree damage (Young and Gilmore 1976; Legg and Schneider 1977; Dunn and others 1980; Cole and Fichtler 1983; Marion 1984). Loss of organic horizons, exposure of mineral soil, severe root exposure, and site enlargement are all changes related to use in a less curvilinear manner (Coombs 1976; Young 1978; Cole and Fichtler 1983; Marion 1984). There is more inherent resistance to these types of change; inflection points and use thresholds are usually higher. Changes in these parameters are easier to limit through manipulation of use intensities on campsites.

The final complication is that even the susceptibility rankings for these parameters do not apply universally. For example, in Grand Canyon National Park, exposure of rock and mineral soil increased as rapidly with increasing use as vegetation loss and more rapidly than increase in penetration resistance (Cole 1985b)—a reversal of the order in the Boundary Waters Canoe Area.

Research does suggest a strong relationship between amount of use and rate of vegetation loss. For example, in an experimental trampling study on alpine meadows in Mount Rainier National Park, vegetation cover was reduced to 50 percent of control values in 3 weeks when trampled at 75 passes per week. At 18 passes per week, it took 8 weeks of trampling for cover to be reduced to 50 percent of controls (Singer 1971). The areal extent of vegetation loss is also strongly related to amount of use (Bratton and others 1978; Cole 1982b). The finding that, at all but very low use levels, increased use has little effect on intensity of vegetation loss and a pronounced effect on area of loss, suggests the value of concentrating and channeling use on a small proportion of any area (Cole 1981b).

On trails, vegetation cover, bulk density, penetration resistance, and trail width relationships are highly curvilinear, as they are on campsites (Dale and Weaver

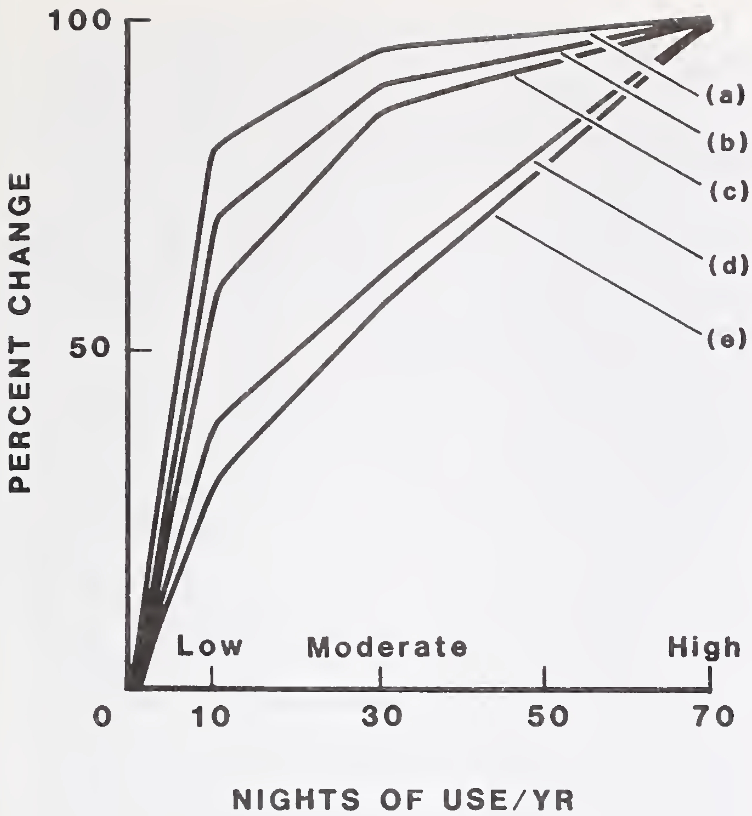

Figure 6.—Relationship between amount of use and (a) tree damage; (b) loss of vegetation cover; (c) increase in penetration resistance; (d) increase in exposed roots, mineral soil, and rock; and (e) campsite area on campsites in the Boundary Waters Canoe Area (Marion 1984). Change is expressed as a percentage of change on high use sites. Numeric use levels are estimated from ordinal classes of low (0 to 12 nights per year), moderate (20 to 40 nights per year), and high use (>60 nights per year).

1974; Crawford and Liddle 1977). Trail depth and the frequency of problems, such as muddiness, are generally not related to amount of use (Dale and Weaver 1974; Helgath 1975; Cole 1983b). Such situations relate more to location and design features, although they obviously must be triggered by some use or construction.

In sum, these results suggest that there is little value, in terms of reduced impact, in limiting use of constructed trails. On campsites, limiting use is only likely to be effective if use levels can be kept very low. This is possible in the majority of most wildernesses, but not in popular destination areas. In popular areas, counteracting the tendency for increased use to increase the areal extent of impact—through channeling and concentrating use—is one of the most effective means of minimizing impact. Because the tipping point for each of these opposing strategies—dispersing use to keep levels low or concentrating use to minimize areal extent—varies greatly between environments, use thresholds need to be identified for major ecosystem types.

Type of Use and Behavior.—The current vogue is to look to visitor education for solutions to wilderness management problems. This reflects a feeling, certainly true but never tested, that parties of the same size vary greatly in the damage they inflict. If all parties can be taught to minimize their impact, then impact problems will be reduced. There are certain problems (such as tree mutilation) that could be entirely eliminated through education. Much trampling damage would still occur, however, although at reduced levels.

Currently, over one-half of all wildernesses have educational programs (Washburne and Cole 1983); a number of studies of how to effectively communicate information to users have also been conducted (for example, Fazio 1979; Roggenbuck and Berrier 1981). In contrast, there has been very little research into what users should be taught. All published papers suggesting educational messages have been personal opinions not based on research. Although many ideas have merit and are not controversial, others are contradictory and oversimplified. Few take into account the need for varying behavior in different environmental and use situations. One exception is an article by Cole and Benedict (1983) that, following a review of literature, suggests different user responses to campsites in various stages of deterioration. It is wasteful to initiate major educational programs without investing some research in what the educational message should be.

One seemingly obvious statement that has frequently been made is that lug-soled boots are much more destructive than tennis shoes or shoes with flat soles. In this case, some research on the subject has been done. Three studies—all done on trails in the East—concluded that, at least under the conditions studied, lug soles are not substantially more destructive than other types of footwear (Whittaker 1978; Saunders and others 1980; Kuss 1983). Kuss, for example, found no significant difference in the volume of soil eroded from stretches of trail trampled by lug-soled and corrugated rubber-soled boots. This lack of difference was found despite increases in soil yield, after 600 and 2,400 trampling passes, that amounted to 1.4 and 1.7 times, respectively, the yield from undisturbed trail. Kuss suggests, however, that differences might be significant if soils were wet. Similarly, perhaps lug soles are more destructive of vegetation on campsites. We will not know unless more conclusive research is undertaken.

Research on the effects of various types of use has also been limited. In wilderness, differences related to party size and mode of travel (hikers vs. stock) are particularly important and amenable to control. The effects of party size have never been formally studied. There is little reason to suspect that large parties will have a more serious impact on trails than a number of small parties. On campsites, however, party size differences could be important.

In response to the need of large parties for more space, campsite area and the size of devegetated areas are likely to increase where sites are used by large parties. However, the severity of impacts in the central part of the campsite is unlikely to increase substantially. Per capita consumption of firewood is less with large parties (Davilla 1979), and reducing party size limits could have the undesirable effect of increasing the number of campsites. Most of these likely outcomes are speculative; they

have not been researched. It is fairly safe to conclude that the current common party size limits of 15 or 25 have had little effect, one way or the other, on recreational impacts.

Differences between impacts caused by hiking parties and parties with stock have received a little more attention, but research has been surprisingly limited. Three studies have compared impacts using experimental trampling (Nagy and Scotter 1974; Douglas and others 1975; Whittaker 1978; Weaver and Dale 1978), two have compared impact on campsites (Frissell 1973; Cole 1983a), and one has compared impact on trails (Dale and Weaver 1974). In addition there are papers by McQuaid-Cook (1978) and Summer (1980) on horse trails and by Strand (1979) on horse effects on experimental trails, as well as the limited research, discussed earlier, on the effects of stock on grazing areas.

Many of the impacts caused by stock are similar to those caused by hikers except that they are more pronounced. Experimental trails produced by 1,000 horse passes were 2 to 3 times as wide and 1.5 to 7 times as deep as trails produced by 1,000 hiker passes. Bulk density increased 1.5 to 2 times as rapidly on horse trails. One-half of the vegetation was lost after 1,000 hiker passes and 600 horse passes in a grassland and after 300 hiker passes and only 50 horse passes in a forest (Weaver and Dale 1978). In a grassland in Waterton Lakes National Park, experimental trampling by horses destroyed vegetation cover four to eight times as rapidly as trampling by humans (Nagy and Scotter 1974). This suggests that multiple trailing and the development of impromptu trails will occur much more rapidly with stock use than with hiker use. Moreover, the trails created will be wider, deeper, more compacted, and less vegetated.

On existing trails, horse use caused more pronounced increases in trail width, trail depth, and litter loss than hiker use. While hiker use tended to stabilize the trail surface, horse use loosened the soil, making it more prone to erosion (Whittaker 1978). McQuaid-Cook (1978) suggested that it is this tendency for shod hooves to loosen soil that leads to the more pronounced incision of equestrian trails documented by Dale and Weaver (1974). The tendency for stock to walk on the downslope side of the trail probably explains the greater width of equestrian trails. Although never studied, equestrian trails are "brushed out" to a greater height and width, resulting in a wider swath of vegetation alteration, and they frequently require more elaborate engineering and more frequent maintenance.

On campsites, quantitative differences between hiker and stock impacts are even more pronounced. More significantly, there are more qualitative differences in type of impact. Although such differences are readily obvious, they have seldom been documented. Frissell (1973) found a sample of sites used by stock parties in what is now the Lee Metcalf Wilderness, MT, to be 10 times as large and have seven times as much exposed mineral soil as backpacker-only sites.

In a more detailed study by Cole (1983a) in the Bob Marshall Wilderness, stock sites were six times as large as backpacker sites. They had over four times as large a devegetated area; they had 11 times as many damaged trees and 25 times as many trees with exposed roots. Stock sites had been more extensively invaded by exotic plants, had lost more of their organic horizons, were more compacted, and had slower infiltration rates. These differences result primarily from the much greater trampling force of horses' hooves and the need to keep horses confined, usually by tying them to trees. Additional impacts result from grazing.

Season of Use.—Theoretically, there are many reasons to expect impact to vary with the time of year use occurs. In particular, soil moisture levels and the phenology of plants when trampling occurs should influence amount of impact. The effect of soil moisture level on the magnitude of trampling impacts on soils was investigated experimentally by Jones (1978). Impacts, particularly loss of macropores, were generally greater at high soil moisture levels. Vegetation damage inflicted by horse trampling was also greater and lasted longer in a wet meadow than in a dry meadow (Strand 1979).

The effect of season of trampling on vegetation loss has been examined experimentally in several studies. Singer (1971), working in an alpine meadow at Mount Rainier, found that vegetation cover was not significantly affected by the time of summer (July 3-August 13) at which trampling occurred. In 10 vegetation types in Waterton Lakes National Park, Canada, Nagy and Scotter (1974) found no consistent difference between trampling in early season (early June-early July) and midseason (late July-early August). In both of these studies, however, no pretreatment measurements were taken, and recovery periods between treatment and measurement were longer for the early season treatment. In a subalpine meadow in Yosemite National Park, Holmes and Dobson (1976) studied differences in the effect of midseason (early August) and late season (early September) trampling on the cover of 14 species. Late season trampling was substantially more damaging to nine species and slightly less damaging to one species; no seasonal difference could be detected for the other four. They attribute this higher vulnerability in late season to reduced plant vigor and drier, more brittle plant parts. There may, however, be little relationship between cover loss immediately after trampling and cover at some time in the future. Early season defoliation of forbs and grasses, for example, has a particularly severe effect on carbohydrate reserves (Donard and Cook 1970). This will affect vigor, reproductive success, and, therefore, long-term vegetation conditions.

Our understanding of the importance of seasonality, then, is extremely limited. Effects appear to be most important on trails and in grazing areas. Most trail management problems can probably be dealt with—without significant research input—through maximizing the advantages of good location and incorporation of design features. Grazing management plans, however, would profit from area-specific research programs, similar to that of Sequoia/Kings Canyon National Parks, that evaluate seasonal differences in vulnerability (DeBenedetti and Parsons 1983).

Environmental Conditions.—Environments vary greatly in their ability to tolerate recreational use. Understanding this variability is difficult, however, because any one place may be resistant to one type of impact and susceptible to another. Moreover, one characteristic of a site, such as good drainage, may raise a site's tolerance level while another, such as a closed canopy, decreases it. Finally, there may be little congruence between resistance—the ability to tolerate use without changing—and resilience—the ability to recover from changes that do occur. More research done outside the field of recreational ecology can usefully add to our knowledge about this topic than any other, with the possible exception of site rehabilitation. Therefore, the following discussion will, of necessity, be more selective than others.

Environmental parameters that affect tolerance can conveniently be divided into vegetation characteristics, soil characteristics, and topographic characteristics. At a higher level of generalization one can also assess the influence of broad ecosystem-level characteristics. Macroclimate also affects tolerance but cannot be influenced by management and, therefore, is not discussed here.

Vegetational characteristics of import are the resistance of individual species, the floristic composition of the vegetation, vegetation cover, and vegetation structure or physiognomy. Of these, most work—starting with Bates (1935)—has been on the resistance of individual species to trampling (Speight 1973; Holmes and Dobson 1976). Morphological characteristics that generally make a plant more tolerant include:

1. A procumbent or trailing, rather than erect, growth form.
2. A tufted growth form.
3. Arming with thorns or prickles.
4. Stems that are flexible rather than brittle or rigid, particularly if they are woody.
5. Leaves in a basal rosette.
6. Small, thick leaves.
7. Flexible leaves that can fold under pressure.
8. Either very large or very small structure.

Physiological characteristics that increase tolerance include:

1. Ability to initiate growth from intercalary as well as apical meristems.
2. Ability to initiate seasonal regrowth from buds below the surface.
3. Ability to reproduce vegetatively and sexually.
4. A rapid growth rate.

Native species that have been identified as particularly resistant to trampling damage in United States wildernesses are listed in table 1. Species have been omitted when evidence is contradictory. For example, *Hieracium gracile* was considered resistant by Coombs (1976) and sensitive by Schreiner (1974), Hartley (1976), and Cole (1982b). Nonnative species are also common on recreation sites in U.S. wildernesses. A list of these species can be found in the paper by Marion, Cole, and Bratton presented at this conference. Some species, such as *Poa pratensis* and *Trifolium repens*, are remarkably widespread and prominent on disturbed sites. In their native habitat in England, they were originally identified as trampling-resistant species by Bates (1935).

Attempts to generalize about the relative tolerance of classes of plants can be useful, although the inevitable exceptions provide considerable ammunition for those who prefer to emphasize the site-specific nature of plant response. Even the response of different individuals within a species varies in response to phenotypic and ecotypic differences (Leney 1974). Survival varies with seasonal cycles, with changes in conditions such as cell turgor, and with differences in associated species. For example, in subalpine meadows in Yosemite, survival rates of a given species were generally about three times greater in mixed communities than in pure stands (Holmes and Dobson 1976).

As mentioned earlier, mature trees and graminoids are generally resistant, mosses are neither highly resistant nor highly sensitive, and lichens and tree seedlings are highly sensitive. Shrubs vary from quite resistant to moderately sensitive; heaths can be particularly susceptible (Emanuelsson 1985). Forbs vary from moderately resistant to highly sensitive. These guidelines, along with consideration of the morphological and physiological characteristics influencing tolerance, can be used to assess the relative durability of different vegetation types. Those types with more abundant resistant plants will generally be more resistant.

Quite a few analyses of the relative resistance of entire species assemblages have been made. The ones that can be most readily compared are the experimental trampling studies. Table 2 ranks 38 plant communities on the basis of their resistance to trampling. Unfortunately, these studies only apply to the initial resistance of plant communities because only damage following one season of trampling was evaluated. Resistance to sustained trampling and resilience are not assessed. Vegetation types for which resistance is relatively high but resilience is low, such as many alpine vegetation types, are rated as resistant even though they may be poor sites for particular types of recreation use and facilities. Also, some very fragile types, such as lush forest/forb types, recover very rapidly after disturbance, if use is not continuous. For example, the "fragile" *Pinus contorta/ Thalictrum occidentale* type (table 2) had much more vegetation cover 1 year after trampling than the much more "resistant" *Dryas octopetala* type (Douglas and others 1975). Generally, those vegetation types with ground cover dominated by graminoids and matted forbs are more resistant than those dominated by shrubs and tall forbs. Studies of change on campsites and along trails in different vegetation types confirm this (del Moral 1979; Cole 1981a).

The effect of amount of vegetation cover on durability is complex. Some communities with a dense ground cover are highly resistant (for example, *Carex nigricans* meadow, Cole 1982b), but some sparsely vegetated types are also resistant (for example, *Pinus albicaulis/Juniperus communis*, del Moral 1979). Perhaps the most important characteristic is the amount of vegetation cover that can survive trampling, because dense vegetation reduces erosion potential.

Table 1.—Resistant native plant species in U.S. wildernesses

Species	Citation(s)
Agave utahensis	Cole (1985b)
Agoseris glauca	Cole (1983a)
Agrostis idahoensis	Thornburgh (1962)
Agrostis lepida	Stohlgren (1982)
Agrostis scabra	Cole (1983a)
Antennaria alpina	Holmes and Dobson (1976)
Antennaria dimorpha	del Moral (1979)
Antennaria lanata	Thornburgh (1962), Cole (1977, 1982b)
Arabis lyallii	del Moral (1979)
Arenaria capillaris	Singer (1971), Schreiner (1974), Hartley (1976), del Moral (1979)
Arenaria congesta	Cole (1985a)
Arenaria obtusiloba	Singer (1971), del Moral (1979)
Aster alpigenus	Singer (1971), Holmes and Dobson (1976), Cole (1977, 1982b)
Aster ciliolatus	Marion (1984)
Bernardia incana	Cole (1985b)
Bouteloua gracilis	Cole (1985b)
Carex aestivalis	Saunders (1979)
Carex bigelowii	Stelmock and Dean (1979)
Carex exserta	Lemons (1979)
Carex microptera	Cole (1982b)
Carex nigricans	Hartley (1976)
Carex phaeocephala	Schreiner (1974)
Carex podocarpa	Stelmock and Dean (1979)
Carex proposita	del Moral (1979)
Carex rossii	Coombs (1976), Cole (1977, 1982b, 1983a)
Carex scopulorum	Holmes and Dobson (1976), Cole (1982b)
Carex spectabilis	del Moral (1979), Cole (1982b)
Chrysothamnus nauseosus	Cole (1985b)
Coleogyne ramosissima	Cole (1985b)
Cowania mexicana	Cole (1985b)
Deschampsia atropurpurea	Thornburgh (1962), Schreiner (1974)
Deschampsia caespitosa	Marion (1984)
Ephedra spp.	Cole (1985b)
Eriogonum pyrolifolium	del Moral (1979)
Fallugia paradoxa	Cole (1985b)
Festuca idahoensis	Schreiner (1974)
Festuca scabrella	Cole (1985a)
Fragaria vesca	Marion (1984)
Geum rossii	del Moral (1979)
Haplopappus acradenius	Cole (1985b)
Juncus castaneus	Hartley (1976)
Juncus drummondii	Cole (1977)
Juncus parryi	Coombs (1976), Holmes and Dobson (1976), Cole (1977, 1982b), Stohlgren (1982)
Juncus tenuis	Sutton (1976), Marion (1984)
Lepidium lasiocarpum	Cole (1985b)
Lewisia columbiana	del Moral (1979)
Luetkea pectinata	Thornburgh (1962)
Luzula hitchcockii	del Moral (1979), Cole (1982b)
Muhlenbergia filiformis	Lemons (1979), Holmes and Dobson (1976), Cole (1982b)
Opuntia erinacea	Cole (1985b)
Oryzopsis kingii	Holmes and Dobson (1976)
Penstemon confertus	Cole (1983a, 1985a)
Penstemon davidsonii	del Moral (1979)
Penstemon procerus	del Moral (1979), Cole (1983a, 1985a)
Phleum alpinum	Hartley (1976)
Phlox diffusa	Singer (1971)
Plantago purshii	Cole (1985b)
Poa alpigena	Stelmock and Dean (1979)
Poa cusickii	del Moral (1979)
Poa epilis	Holmes and Dobson (1976)
Polygonum cilinode	Saunders (1979)
Rhus trilobata	Cole (1985b)
Rosa acicularis	Marion (1984)
Rubus strigosus	Marion (1984)
Schizachne purpurascens	Marion (1984)
Senecio pauperculus	del Moral (1979)
Senecio resedifolius	Hartley (1976)
Sibbaldia procumbens	Dale and Weaver (1974), Cole (1977, 1982b)
Smilax herbacea	Saunders (1979)
Solidago missouriensis	Cole (1983a, 1985a)
Solidago multiradiata	Cole (1977)
Stipa occidentalis	Cole (1983a)
Tauschia (Hesperogenia) stricklandii	Thornburgh (1962)
Trisetum spicatum	del Moral (1979), Stelmock and Dean (1979)
Xerophyllum tenax	Cole (1983a, 1985a)
Yucca baccata	Cole (1985b)

Table 2.—Relative resistance of plant community types to trampling damage

Plant community types[1]	Resistance to: Light[2] trampling	Heavy[3] trampling	Both[4]
1. *Pinus contorta/Thalictrum venulosum* (lodgepole pine forest)	VS	VS	VS
2. *Populus tremuloides/Heracleum lanatum* (aspen forest)	VS	SS	VS
3. *Populus tremuloides/Symphoricarpos albus* (aspen forest)	VS	SS	VS
4. *Vaccinium membranaceum* (subalpine huckleberry shrubland)	SS	VS	VS
5. *Phyllodoce glanduliflora* (subalpine heath shrubland)	SS	VS	VS
6. *Carex rostrata-C. aquatilis* (sedge marsh)	VS	SS	–
7. *Cassiope mertensiana* (subalpine heath)	SS	VS	SS
8. *Abies lasiocarpa/Luzula hitchcockii* (subalpine fir forest)	SS	SS	SS
9. *Aster alpigenus-Phlox diffusa* (alpine cushion community)	SS	SS	SS
10. *Picea engelmannii/Arnica latifolia* (Engelmann spruce forest)	SS	N	SS
11. *Valeriana sitchensis* (subalpine forb meadow)	SS	N	SS
12. *Picea engelmannii/Thalictrum occidentale* (Engelmann spruce forest)	SS	N	SS
13. *Pseudotsuga menziesii/Symphoricarpos albus* (Douglas-fir forest)	SS	SS	N
14. *Picea glauca/Vaccinium uliginosum* (boreal spruce forest)	SS	—	–
15. *Antennaria lanata-Carex nigricans* (alpine snowbank community)	SS	N	N
16. *Holcus lanatus-Agrostis stolonifera* (acid grassland)	N	SS	–
17. *Deschampsia flexuosa-Holcus lanatus* (acid grassland)	N	SS	–
18. *Xerophyllum tenax* (subalpine beargrass meadow)	N	SS	N
19. *Larix occidentalis/Linnaea borealis* (western larch forest)	N	N	N
20. *Lupinus lepidus-Carex phaeocephala* (alpine stone-stripe community)	N	N	N
21. *Anemone occidentalis-Trollius laxus* (subalpine forb meadow)	N	N	N
22. *Antennaria lanata-Hieracium gracile* (subalpine forb meadow)	N	–	–
23. *Phlox diffusa-Carex phaeocephala* (subalpine cushion community)	N	–	–
24. *Empetrum nigrum* (sand dune heath)	N	N	SR
25. *Arrhenatherum elatius-Holcus lanatus* (neutral grassland)	N	SR	–
26. *Pinus contorta/Vaccinium caespitosum* (lodgepole pine forest)	N	SR	SR
27. *Trollius laxus-Aster foliaceus* (subalpine forb meadow)	N	SR	SR
28. *Luetkea pectinata* (subalpine mat plant community)	N	SR	SR
29. *Calluna vulgaris-Deschampsia flexuosa* (heath-grassland)	SR	N	–
30. *Pinus albicaulis/Vaccinium scoparium* (whitebark pine forest)	SR	N	SR
31. *Arctostaphylos uva-ursi-Carex eburnea* (heath-grassland)	SR	–	–
32. *Dryas octopetala* (alpine cushion community)	SR	SR	VR
33. *Aster alpigenus-Festuca idahoensis* (subalpine meadow)	VR	–	–
34. *Pinus contorta/Xerophyllum tenax* (lodgepole pine forest)	VR	VR	VR
35. *Festuca scabrella-F. idahoensis* (grassland)	VR	VR	VR
36. *Festuca scabrella-Danthonia intermedia* (prairie grassland)	VR	VR	VR
37. *Poa pratensis-Festuca idahoensis* (grassland)	VR	VR	VR
38. *Carex nigricans* (subalpine sedge meadow)	VR	VR	VR

[1]Sources are as follows: Nagy and Scotter 1974 (1,2,3,6,8,10,18,27,32,36); Landals and Scotter 1974 (4,7,11,28,38); Landals and Scotter 1973 (5,21); Singer 1971 (9); Schreiner 1980 (14); Bell and Bliss 1973 (15,20); Harrison 1981 (16,17,25,29); Schreiner 1974 (22,23,33); Hylgaard and Liddle 1981 (24); Weaver and Dale 1978 (30,37); Bowles and Maun 1982 (31); Cole 1985c (12,13,19,26,34,35).

[2]The index for resistance to light trampling is the number of passes required to reduce cover to 50 percent of original conditions. Classes are as follows: very susceptible (VS) (0 to 25 passes); somewhat susceptible (SS) (26 to 100 passes); neither susceptible nor resistant (N) (101 to 250 passes); somewhat resistant (SR) (251 to 500 passes); very resistant (VR) (more than 500 passes).

[3]The index for resistance to heavy trampling is relative or percent cover after 800 passes. Classes are as follows: VS (0 to 3 percent); SS (4 to 7 percent); N (8 to 15 percent); SR (16 to 35 percent); VR (more than 35 percent).

[4]The index for both is essentially the mean relative or percent cover across the range from 0 to 800 passes. Classes are as follows: VS (0 to 15 percent); SS (16 to 25 percent); N (26 to 35 percent); SR (36 to 50 percent); VR (more than 50 percent).

The most significant effect of vegetation structure relates to degree of canopy closure. Many studies have observed a tendency for more open communities to be more resistant than closed forests. For example, in a recent study in the Boundary Waters Canoe Area, Marion (1984) found that campsites with 75 to 100 percent tree cover lost 77 percent of their vegetation cover, while sites with 0 to 25 percent tree cover lost only 43 percent. This finding is all the more striking in that vegetation loss did not differ significantly among the seven forested plant communities studied.

This relationship between canopy cover and vegetation impact has a strong theoretical basis. Grime (1979) hypothesized that no plants are well adapted to environments characterized as both high in stress (in this case low light intensity) and high in disturbance. Adaptations to low light intensities make a plant particularly susceptible to trampling damage (Cole 1979). Moreover, the susceptibility of dense forests has been demonstrated in many places—the Pacific Northwest (Schreiner and Moorhead 1979; Cole 1981a), the northern forests (Marion 1984), and the Appalachians (Ripley 1962).

Important soil characteristics that influence amount of impact are soil texture, soil structure, organic matter, moisture, fertility, and depth. Regarding soil textures with the fewest limitations for campsites and trails, Montgomery and Edminster (1966), Epp (1977), and Fay and others (1977) recommend medium-textured soils—sandy loams, fine sandy loams, and loams. Such soils generally have good drainage, are not highly erodible, and have high potential for plant growth. Their major drawback is that their wide range of particle sizes makes them particularly susceptible to compaction (Lull 1959). Coarse soils generally resist water erosion because large particles are neither easily detached nor easily moved. However, their structural instability makes them vulnerable to trail widening and their low water-holding capacity and cation-exchange capacity make them relatively impoverished environments for plant growth. Such drawbacks are likely to be more serious for trails than for campsites. Nevertheless, coarse soils are clearly a better alternative than fine-textured soils. Silts and fine sands are highly erodible because soil particles are both readily detached and moved (Baver 1933). Moreover, silt soils are prone to needle ice formation when wet and become dusty when dry. The permeability of soils high in clay is greatly reduced when compacted. This promotes increased runoff and erosion. Although clay particles resist detachment, they are readily moved by running water. Clays also have little ability to support loads because they deform readily when wet. They are generally sticky when wet and they dry slowly (Leeson 1979).

The role of stones and rocks in soil is complex. Leeson (1979) suggested that they are desirable up to a volume of 25 percent of the soil because they inhibit compaction and increase the resistance of soil particles to entrainment. Above this volume, they make footing difficult and construction and maintenance costly. Bryan (1977) noted that rocks are generally advantageous unless trail degradation has advanced to the point where soil coherence is completely destroyed. Once stones are loose on the trail, rocks increase erosion potential because they increase the turbulence of running water and, when moved, corrode the trail themselves. Summer (1980) suggested not categorically removing stones from trails because this frequently leads to erosion of underlying fines, exposing more rocks. Many of the most severe erosion problems are in stone-free, homogeneous-textured soils (Root and Knapik 1972; Bryan 1977). This textural limitation may explain the problems with trail incision and development of multiple trails in mountain meadows.

Well-developed soil structure promotes drainage; this is generally good. Trampling disrupts structure, particularly when soils are high in clay and when trampling occurs when soils are wet. This loss of structure makes soils more prone to erosion. Generally soils with a granular structure and a high proportion of water-stable aggregates have the fewest limitations for recreational use (Leonard and Plumley 1979). Because trampling destroys both, it is not clear how important these properties are. Soil pans, such as the iron pan described by Bryan (1977), impede drainage and can become more heavily cemented and impenetrable in compacted soils, but, once exposed, their resistance can also serve to inhibit further incision.

The advantages and disadvantages of organic matter are also complex, varying with amount, type, and associated soil characteristics. Organic soils—as opposed to mineral soils—have particularly low bearing strengths when wet. Consequently, they are highly vulnerable to puddling (Bryan 1977) and quickly become wide, muddy quagmires where crossed by trails. Thick surface organic horizons, under forest, shield the mineral soil from compaction (Legg 1973; Marion and Merriam 1985) and inhibit runoff and erosion (Lowdermilk 1930). They also inhibit the germination of most plant species, leading to reduced vegetation cover. Incorporated into the mineral soil, organic matter promotes structural development, which enhances drainage (Leonard and Plumley 1979), inhibits compaction (Dotzenko and others 1967; Marion and Merriam 1985), helps resist dispersion and detachment of soil particles, and promotes plant growth due to its positive influence on water-holding capacity and nutrient availability (Leonard and Plumley 1979).

Soil moisture, as with most other soil parameters, is best in moderate quantities that promote plant growth but do not cause the problems common to poorly drained, wet soils. Moisture decreases the load-bearing capacity of many soils, making them more prone to compaction, puddling, and muddiness problems. Moisture problems are most severe with fine-textured soils and are most likely to cause problems on trails. Moisture also exacerbates the damage inflicted by stock on grazing areas (Strand 1979). Probably a majority of trail problems, in the West at least, result from locating trails in areas that are poorly drained or have high water tables (Root and Knapik 1972). It is often possible to identify vegetational indicators of the soils with high moisture content that are likely to develop muddiness problems unless avoided or bridged (Cole 1983b).

Limited data suggest that vegetation on moderately fertile soils is more resistant than that on highly fertile soils, with vegetation on infertile soils being least tolerant (Ripley 1962; Papamichos 1966; Kellomäki and Saastamoinen 1975; Harrison 1981). There are insufficient data, however, to evaluate how generally applicable or significant such a tendency is.

Finally, deeper soils are often better suited to recreational use than shallow soils (Fay and others 1977). This is primarily a reflection of the erodibility of very shallow soil and the vulnerability of vegetation established in pockets of thin soil. This vulnerability, attributable to very thin soil, is likely to explain the common assumption that mosses are fragile. Mosses, growing on bare rock or in shallow soils, are susceptible to being dislodged. In deep soils, trampling experiments, almost without exception, have shown them to be relatively resistant. The most resistant sites of all are bedrock.

Table 3 summarizes, in very general terms, how these soil properties influence tolerance. Although these general patterns have been identified, much more needs to be learned about how significant these factors are to the maintenance of desirable conditions. The most serious problems, or at least those that have received most attention, occur where trails are located on soils with homogeneous textures (deeply incised, braided trails in meadows) or on wet mineral or organic soils (wide, muddy quagmires).

Locational characteristics include slope steepness and position, topography, aspect, and elevation. On campsites, slopes are generally negligible. On trails, the angle of slope, both along and across the trail, and the position of the trail—close to the top or bottom of a slope—all influence potential for deterioration. These variables all affect the amount and velocity of water running down the trail.

As slope angle along the trail increases, so does erosion potential. Coleman (1981) developed regression models that related path width and depth to the square of the path slope. Her data suggest little problem until slopes exceed 12 to 13 degrees; beyond this, problems increase exponentially. On relatively flat trails, Cole (1983b) found that path depth increased significantly as slope increased, but slope only explained 8 percent of the variation in depth and was not related to path width. Water drainage devices and frequent maintenance can minimize trail problems, even on steep slopes. Moreover, trails with no slope at all have their own problems, primarily a result of poor drainage.

Trails oriented parallel to the slope channel water directly downslope and often deteriorate more dramatically than trails oriented perpendicular to the slope (Bratton and others 1979). Trails located high on slopes have smaller watersheds and, therefore, less erosion potential than trails close to the base of slopes. In valleys covered by complex glacial till deposits, trails near the base of slopes frequently intercept perched water tables (Helgath 1975).

Quite variable results are available for the effect of elevation on site durability. In Great Smoky Mountains National Park, Bratton and others (1978, 1979) reported positive correlations between elevation and both campsite and trail deterioration. Although no data are available, Fay and others (1977), working in the Northeast, suggested that deterioration problems increase with elevation. In the Sierra Nevada, Dykema (1971) found campsite alteration to be greater at both low and high elevations than at moderate elevations. An examination of the tolerance of the plant communities in table 2 shows no relationship between durability and elevation.

The complexity of factors influencing environmental tolerance makes it unlikely for a variable like elevation to relate strongly to tolerance. Perhaps the most consistent effect of increasing elevation is a decrease in length of the growing season. This, along with locally variable factors such as frequent high winds and needle ice, often makes resilience lower at high elevations. Alpine vegetation, for example, is frequently quite resistant (Grabherr 1982 and table 2), but resilience is low. In desert regions, however, higher moisture levels at higher elevations may compensate for a shorter growing season and lead to greater resilience at high elevations. Other characteristics that increase vulnerability and are more common at higher elevations include organic soils, the homogeneous fine-textured soils that are associated with certain types of glacial deposits, areas with poor drainage, and steep trail pitches. Such problems do not increase with elevation in all wildernesses, however, and at almost any elevation sites vary greatly in their level of tolerance.

The effect of aspect is similarly complex. One of the most frequent aspect-related problems occurs high in the mountains, where late snowmelt on northerly aspects contributes to trail widening and erosion through the medium of trampling of water-saturated soils and subsequent channeling of meltwater down the entrenched trail (Price 1981). Under droughty, low-elevation conditions, however, one might expect the more mesic northerly aspects to be more tolerant. In Iowa, Dawson and others

Table 3.—Relationships between soil characteristics and susceptibility to impact

Soil property	Level of susceptibility: Low	Moderate	High
Texture	medium	coarse	homogeneous; fine
Organic context	moderate	low	high
Soil moisture	moderate	low	high
Fertility	moderate	high	low
Soil depth	none	deep	shallow

(1974) found that trails on north-facing slopes were less compacted and lost less ground cover than trails on flood plains or south-facing slopes. In northern Utah, vegetation resistance to simulated trampling was greatest on steep northeast slopes, at low elevations (Cieslinski and Wagar 1970). While such generalizations might provide useful guidelines within localized areas, their general utility is questionable.

At the ecosystem level, some have proposed that tolerance increases with primary productivity (Liddle 1975b) and with more advanced successional stages (Goldsmith 1974). Liddle felt that productivity summarized potential for regrowth and the overall hospitality of the environment. Data from five studies generally support the relationship, provided that only the productivity of the ground flora in woodland is considered. However, when quite different physiognomic types are compared, the relationship breaks down. Desert shrub, for example, is notably unproductive and yet it is more resistant to low to moderate levels of recreation use than coniferous forest vegetation (Cole 1983a, 1985b). Perhaps productivity might relate more to resilience than to resistance.

Goldsmith also noted—once he stated that earlier stages in succession were more fragile—that this principle must be qualified by differences in the tolerance of growth forms and by limiting environmental variables. Thus, a seral grassland stage may prove to be more resistant than a climax forest because grasses are more tolerant of trampling than broad-leaved forbs. The theory behind the importance of successional stage stems from the concept that diversity begets stability—that more diverse environments are less susceptible to disturbance. Because later successional stages tend to be diverse, they should be more tolerant of recreational pressure. This concept is generally considered to be an oversimplification and this is certainly true for its application to recreational tolerance. *Carex nigricans* meadows, for example, have low diversity, and yet they are very resistant after soils dry out (table 2).

In sum, it appears that vegetation resistance is probably most highly dependent on the growth form of the constituent species. As this can be highly variable locally, resistance can vary greatly over short distances (Cole 1985c). Resilience, in contrast, is more dependent on environmental factors such as soil fertility, length of the growing season, sunlight levels, and moisture levels. Therefore, it may be possible to demonstrate reduced resilience at higher elevations and with lower primary productivity and diversity. Further work might lead to better theoretical development along these lines.

There is little doubt that an improved understanding of how environmental factors influence impact problems would be tremendously useful to management. By reducing impact through improved site selection, more people can enjoy the wilderness with less impact. Given the complex variables involved and great variability from place to place in the significance of different variables, it is important for wildernesses to develop their own guidelines concerning durable and fragile locations. Many of the best examples of site-specific analysis of impact problems and how they can be avoided are Canadian (for example, Lesko and Robson 1975; Root and Knapik 1972; Landals and Knapik 1972; Landals and Scotter 1974). These studies assess the nature of problems, their causes, how they relate to use and environmental variables, and provide management guidelines to avoid future problems and correct existing problems. In this country, four examples of site-specific research to guide management are: (1) Fay and others' (1977) guidelines for locating and designing overnight facilities in the Northeast, (2) Summer's (1980) ratings of erosion potential and likely trail deterioration problems for major landform units in Rocky Mountain National Park, (3) Cole's (1982a) descriptions of design and locational considerations for major vegetation communities in the Eagle Cap Wilderness, and (4) DeBenedetti and Parsons' (1983) meadow type-specific management recommendations for grazing. Management of most other resources benefits from knowledge about environment variability and its importance to management; wilderness should be no different.

Evaluations of Management Techniques

Remarkably few attempts have been made to evaluate the effectiveness of different techniques that are or could be used to minimize ecological impacts. Few natural experiments have assessed the consequences of management actions that have been taken, and even fewer papers have reviewed existing data and theory for their application to management. This contrasts with the social-psychological side of recreation research where natural experiments have frequently been used to evaluate the effectiveness and acceptability of such techniques as use rationing (Stankey 1979) and the use of information to disperse use (Roggenbuck and Berrier 1981).

Several studies have evaluated the effectiveness of campsite closures as a means of reducing impact. Temporary closures in the Selway-Bitterroot Wilderness were generally ineffective. Little improvement in condition occurred over 8 years of closure. Meanwhile, new campsites developed near the closed ones; after 8 years, deterioration on the new sites was almost as pronounced as on the old sites. Poor success reflected slow natural recovery rates, the lack of assisted recovery, and poor compliance with closures (Cole and Ranz 1983). This suggests that rest-rotation is not a practical means of reducing impact. Slow rates of recovery have also been documented in Sequoia/Kings Canyon National Parks (Parsons and DeBenedetti 1979; Stohlgren 1982).

Limited data from Kings Canyon National Park suggest that implementation of a 1-night length-of-stay limit and a ban on wood fires has reduced campsite damage. One currently little-used site has recovered much of its litter and duff cover and woody fuels following imposition of these regulations (Parsons 1983). Finally, a series of meadow condition assessments, also from Sequoia/Kings Canyon National Parks, demonstrate the effectiveness of a number of actions taken to reduce stock damage (Sumner 1968).

Cole (1981b) reviewed the literature for implications about the likely success of reducing campsite impact

through use dispersal and campsite closures. He concluded that dispersal is likely to aggravate impact problems, except in lightly used areas, that temporary closures are seldom effective, and that permanent closures should be evaluated on an individual basis, as opposed to blanket policies such as 200-foot setbacks from water. Craig (1977) advanced his opinions about certain campsite management techniques, recommending containing use to designated sites in heavy-use areas, limiting party size, zoning, hardening sites and providing waste-handling facilities where necessary, and restoring sites. Fay and others (1977) provided a useful summary of location and design criteria for overnight facilities, most applicable to the Northeast. Cole and Dalle-Molle (1982) put together a handbook for planning for and managing campfire impacts.

Trail management is less complex and generally better understood than campsite management. Proper location, design, and maintenance are more important than visitor management (Cole 1983b). Proudman (1977) provided a good summary of how to design, build, and maintain trails in such a way that damage is minimized. In my opinion, little further research on trail management is needed, although individual areas must develop area-specific methods for dealing with their unique situation and problems. This may require correlating trail problems with environmental conditions and monitoring the effectiveness of alternative designs for handling problems (Cole 1983b).

Site Rehabilitation

Significant effort is being expended in attempts to rehabilitate highly impacted backcountry sites. Such efforts are necessary due to the long recovery periods required when recovery is not assisted. A considerable body of information relevant to rehabilitation is accumulating, although it is widely dispersed and most is not directly applicable to wilderness. Perhaps the best initial sources of information on rehabilitation of wilderness sites—although both are now over 5 years old—are Cole and Schreiner's (1981) bibliography and the proceedings of the Recreational Impacts on Wildlands Conference (Ittner and others 1979). A tremendous amount of experience is not being shared because documentation and dissemination of results are poor.

Most of the rehabilitation work in backcountry that has been written up (but not published) is from the Pacific Northwest. Rehabilitation programs at North Cascades, Olympic, and Mount Rainier National Parks have been in the forefront. For this region, considerable progress has been made toward identifying suitable species for either seeding or transplanting (Miller and Miller 1976; Schreiner 1977). Greenhouse propagation techniques for producing transplants have been developed by Miller and Miller (1979). Other papers provide hints about the mechanics of transplanting, from guidelines concerning transplant size to suggestions about watering and fertilization (Miller and Miller 1976; Scott 1977). Two excellent reports (Dalle-Molle 1977; Miller and Miller 1977) discuss how to handle specific problems, such as frost heaving and keeping people off transplants. In the Pacific Northwest, transplanting is generally more successful than seeding, watering is important, and the need for fertilization is questionable and unresolved. One study in the Northeast found fertilization and liming to be ineffective in increasing vegetation cover, although the study's conclusion was to increase amounts, not discontinue the practice (Fay 1975).

One of the few documented experiments testing means of rehabilitating trails occurred on a stretch of multiple trails in Yosemite National Park (Palmer 1979). Of 22 techniques tried, the most successful involved cutting off the sod ridges between trails at the level of the trail tread and stacking them in the shade. The soil beneath both trails and ridges is dug up and sand is added to bring the area up to the level of the surrounding meadow. Finally, the stacked sod is divided into transplant plugs and planted. Considerable progress in rehabilitation could be made if those working with rehabilitation would invest more energy—as Palmer did—in documentation, experimentation, monitoring, and communication of results.

A lot of work was done by Forest Service researchers, in the 1960's particularly, on rehabilitation of developed campgrounds. In several studies involving attempts to establish grass, shrubs, and small trees on campsites in the Southeast, the most conclusive finding was that reducing overstory canopy cover greatly increases grass production (Cordell and Talhelm 1969; Cordell and James 1971; Cordell and others 1974). In Idaho and Utah, watering, seeding, and fertilizing maintained high levels of nonnative grass on campsites (Beardsley and Wagar 1971; Beardsley and others 1974). In Maryland state parks, mulching also contributed to revegetation success (Little and Mohr 1979). All studies stress the overriding importance of designing traffic flow to keep people off vegetated parts of the site.

Research on rehabilitation of nonrecreational sites varies greatly in its applicability to wilderness. Revegetation of high-altitude lands has been addressed in several places—a series of conferences on the topic (such as Kenny 1978), a Forest Service research program focused on the Beartooth Plateau (Brown and others 1978), and a history of work on depleted rangelands (for example, Hull 1974). Such studies help in the identification of factors limiting success, choice of species for rehabilitation, and, to a lesser extent, rehabilitation techniques. Because mining disturbance and rangelands are concentrated in the West, more research is available there than in the East.

Some of the most interesting work is basic research on the factors that limit revegetation success. Perhaps the most notable program here is the work of Marchand and coworkers (Marchand and Roach 1980; Marchand and Sproul 1981; Roach and Marchand 1984) on *Arenaria groenlandica*, *Juncus trifidus*, and *Potentilla tridentata*, common native species found in alpine areas along the Appalachian Trail in New Hampshire. Detailed autecological work has provided more understanding about seed production, dissemination, and germination and the early growth and survival of these species. Major limitations to recolonization by these species are lack of vegetative reproduction, poor seed dissemination, and frequent mortality by frost heaving.

Schreiner (1982) studied the autecology of a native (*Poa incurva*) and a nonnative (*Poa pratensis*) colonizer of disturbed sites. He concluded that traditional site restoration techniques, such as watering and fertilization, would favor *Poa pratensis* at the expense of native species. Research on mycorrhizae is also beginning to reveal their role and importance in rehabilitation (Reeves and others 1979).

The research on revegetation is too extensive to review adequately in several pages. However, much more is needed if we are to increase the cost-effectiveness of the rehabilitation work already underway. The top priority, as mentioned earlier, should be better documentation of what is being done and its success. Major issues that should be addressed include (1) advantages and disadvantages of transplanting versus seeding, (2) the value of scarification, (3) the value of fertilization, (4) the value of and recommendations for mulches, (5) how to reduce frost heaving problems, and (6) whether or not there should be any role for nonnative plants.

In addition, more basic research could improve our understanding of factors that limit the establishment and spread of vegetation. Our poor understanding of the impact process and the importance of documented impacts to ecosystem functioning is a serious problem. We need to understand why many transplants survive year after year, but do not spread. We need to understand more about the importance of mycorrhizae, and we need more autecological studies like those of Marchand and Schreiner.

Impact Monitoring

One final area of research is the development of monitoring systems. Most effort has gone into systems for identifying change on campsites. If replicable, the sampling procedure of any campsite impact study could be the basis of a monitoring system. A number of studies have proposed procedures specific to the task of monitoring, however.

Perhaps the earliest monitoring research was Walker's (1968) exploratory attempt to use panoramic photographs, monoscopic photographs, and stereophotogrammetry. On the basis of his suggestions, 360-degree panoramic photo mosaics, taken from permanent points located near the center of campsites, were incorporated into a monitoring system used by the Selway-Bitterroot Wilderness. While gross changes—fallen trees, new fire rings, and so on—could be identified, it was difficult to identify ground cover changes and any changes beyond the closest trees. Although photographs are unlikely to completely replace the need for field measurements, they can help identify sites for future reassessments, record campsite features not measured in the field, and provide a visual supplement to data collected in the field. Brewer and Berrier (1984) provide useful guidelines for the use of ground-based photography.

In open areas, aerial photography can be used to monitor impacts. Boorman and Fuller (1977) and Price (1981) provided examples of trail deterioration analysis based on air photo interpretation. In Grand Canyon National Park, devegetated trails and camping areas on beaches along the Colorado River have been monitored with large-scale, low-elevation aerial photographs.

Field measurements taken at campsites vary greatly, particularly in level of precision and consumption of time. Hendee and others (1976) proposed a Code-A-Site form for inventory and monitoring. The only site condition information they asked for was an undefined judgment as to whether prior impact had been extreme, heavy, moderate, or light. Some precision was added to this system when managers of the Selway-Bitterroot provided written definitions for these four classes. This was also the approach advanced by Frissell (1978). He proposed a system of five condition classes based on extent of vegetation loss, litter loss, tree root exposure, erosion, and tree mortality.

More elaborate systems have been suggested by Parsons and MacLeod (1980) and Cole (1983c). These systems quickly rate campsites on the basis of such impact parameters as vegetation loss, change in species composition, campsite area, area of barren core, campsite development, campsite cleanliness, loss of organic matter, social trails, tree mutilation, and tree root exposure. Compared to "condition class" systems, these have the advantage of more information, at little additional cost, and disaggregated data on individual impact parameters. Thus, they are more flexible, more generally useful, and more likely to provide insight into exactly how a site is changing over time.

The major alternative to such rapid estimation techniques is a measurement system for campsite area and devegetated area first developed by Schreiner and Moorhead (1979) for use at Olympic National Park. Mount Rainier National Park adapted Schreiner and Moorhead's system of radial measurements to produce reasonably accurate sketch maps to monitor campsite changes. Although quite time consuming, such a system will detect more subtle changes than rapid estimation systems.

Generally, research on campsite monitoring is sufficient for most needs. The next step is transfer of technology and adaptation of existing systems to meet local needs.

TECHNOLOGY TRANSFER

It is difficult to evaluate how extensive technology transfer is—both because it is impossible to keep track of all applications and because it is seldom clear where the idea behind an action came from. The best opportunities for technology transfer are provided in situations where the researcher and the manager have a shared interest in a project and cooperate from the beginning. This situation is most common in the Park Service, although cooperative examples elsewhere do occur. Transfer also becomes easier—or at least is more easily measured—the more tangible the research product. Thus, probably the foremost readily traceable example of successful technology transfer has been the recent spread of campsite monitoring systems.

Following the development of the Code-A-Site form (Hendee and others 1976), quite a few wildernesses inventoried their campsites using the form. Common problems that arose were insufficient information on campsite condition and uncertainty about what to do with the information collected. In Olympic National Park, more relevant information was developed for use with the form and systems for data analysis and periodic reassessments of conditions were developed (Schreiner and Moorhead 1979). Neighboring Mount Rainier National Park borrowed from and modified this innovation.

A compromise between the time-consuming Olympic-Mount Rainier type of system and the low-information Code-A-Site system was developed for use in Sequoia/Kings Canyon National Parks (Parsons and MacLeod 1980). It is also being used in neighboring Yosemite National Park. Cole (1983b) modified the Sequoia/Kings Canyon multiple estimated parameters system by incorporating new parameters, improving estimation techniques, and keeping data disaggregated. Cole's paper also linked the campsite monitoring system to the Limits of Acceptable Change (LAC) planning framework for wilderness management—an attempt to base management on specific objectives (Stankey and others 1985). The combination of a tangible product that is simple to apply, not time consuming, and fulfills a recognized management need led to rapid spread. Within the Forest Service, the Pacific Northwest Region (Oregon and Washington) is adopting the system. It has spread widely in the Northern Rockies (for example, Bob Marshall, Mission Mountains, Rattlesnake, Lee Metcalf, and Frank Church-River of No Return Wildernesses), and a few areas in the Southwest (for example, Superstition Wilderness) are experimenting with it. Through Marion (1984), the system spread first to the Boundary Waters Canoe Area and then to National Park areas along the Delaware River in the East. Through Cole's (1985b) work at Grand Canyon, a similar system is also being applied there.

Another example of successful research application is the management program at Sequoia/Kings Canyon National Parks. This success reflects close cooperation in the Park Service between research and management. At Sequoia/Kings Canyon, management has profited from research on campsite recovery (Parsons and DeBenedetti 1979; Stohlgren 1982), research on meadow condition and response to clipping (DeBenedetti and Parsons 1983), and extensive use of data on use permits and campsite monitoring forms. Particular achievements include a rational use limitation program (Parsons and others 1981), prescription of a variety of actions to deal with problems at a very high-use lake basin (Parsons 1983), and proposal of a comprehensive stock management program (DeBenedetti and Parsons 1983).

Unfortunately, these successes are far outweighed by the lack of research application. Three principal barriers to effective technology transfer are: (1) an adequate research base has not been developed, (2) too little attention has been paid to drawing management implications out of research results, and (3) managers have not always looked to research for solutions to their problems.

Currently, the problem of an insufficient research base is the most serious and basic of these barriers. Without a research base to start with, the other problems are moot. Current allocation of resources between management and research—with very little funding in research—may be adequate for dealing with current "brushfire" problems but is not cost-effective in the long-term because little investment is made in improving future management. The current allocation of recreation management research almost entirely into social research also seems unbalanced. It ignores the primary goal of wilderness management—maintenance of natural conditions—and the fact that ecological impact problems are less reversible than social problems.

The current situation is well illustrated by how resources are being allocated in minimum impact education programs. In 1980, over one-half of all wildernesses were investing management time and funds in such programs (Washburne and Cole 1983), and there are undoubtedly many more areas that now have such programs. Investment in research, both on what to teach and how to teach cost effectively, has been minimal, however. Moreover, what has been done is entirely on how to teach rather than what to teach—in my view, a classic case of getting the cart before the horse. So now we are in a position of investing scarce wilderness management funds in a curriculum based entirely on personal judgments and opinions (many of them good, I should say). Even a minor investment in what to teach and how to do it would more than pay for itself in little time.

Much of the recreational ecology research that has been done provides little basis for management application. A lack of careers in the field has meant that studies have generally been limited to short-term studies at one place and time. Consequently, results are generally superficial, there is no opportunity to gain the insights that come with experience, and there has been little chance to compare results from a number of places to assess the general applicability of conclusions. This helps explain the lack of theoretical development in the field. Because most studies are done by students at the master's level or as one-time projects, there has been a strong tendency to undertake relatively simple projects generally cut from the same mold. Consequently, we have numerous studies documenting changes in vegetation and soil conditions on recreation sites with little idea of significance.

Designing research so that it is most useful to management is also difficult given the current situation. Cooperation between research and management is limited. Aside from a few Park Service researchers, no agency researchers work in the recreational ecology field. In a few situations, academicians have worked closely with managers (for example, Marion 1984), improving the likelihood of future application, but all too frequently this is not the case. Short-term involvement in the field gives little opportunity for developing the kind of rapport that facilitates the technology transfer process.

Lack of careers also means less attention is given to the management of ecological impacts in recreation management programs in colleges and universities; recreation departments are staffed almost entirely by social

scientists. With little training in management of ecological impacts, it is difficult for managers to search effectively for solutions to impact problems. This problem is aggravated by the schedules of most wilderness managers; they are sufficiently busy to preclude much time searching the literature for innovative management solutions.

If careers in recreational ecology were possible, we could build a more substantial research base and improve training of recreation professionals. Over a career, a researcher could gain insights from experience, develop the management implications of research, and build rapport with managers. The challenges of designing research to deal with critical management questions and encouraging the application of results would remain, but the outlook would improve significantly.

RESEARCH GAPS AND FUTURE DIRECTIONS

Problems with maintaining natural vegetation and soil conditions in wilderness are serious. They undermine the intentions of the Wilderness Act and, in many cases, are irreversible. Many impacts are readily obvious even to untrained observers, and simple solutions, such as closing sites to use, are usually available. However, detection of subtle changes and development of innovative solutions that minimize elimination of recreational opportunities and avoid simply moving problems around demand research beyond the "documentation of the obvious" that has characterized the recreational ecology field.

In my opinion, the primary reason for the poor state of the art is lack of support for such research. Despite allocation of almost 90 million acres to wilderness, a land classification with a primary goal of maintaining natural conditions, no continuing program exists in wilderness impact research. Consequently, available research is generally confined to a large number of descriptive studies that lack much time frame, theory, or comparability. Unless support for a critical mass of researchers is forthcoming, there is little to suggest that the current situation will improve appreciably.

To improve, changes need to be made in research design and approach. There is a critical need for more longitudinal studies. The current reliance on cross-sectional studies provides us with a perspective confused by spatial and temporal variability. Cause and effect are difficult to unravel, and there is little to suggest process or the significance of long-term processes. Study periods, for both before-and-after studies and experimental studies, need to be lengthened. Long-term studies will be possible only if researchers have long-term support.

More specialized, detailed studies of the impact process are also needed. Researchers have always had to be "jacks of all trades" to deal with the wide variety of impact problems. Now we need researchers with specialized knowledge, both in subject matter and methodologies. We need to go beyond measurements of soil compaction, for example, to studies of effects on more basic soil properties, such as aeration, micro-organisms, and mycorrhizae. At an even more fundamental level, we need to understand relationships between these altered soil characteristics and plant establishment, growth, and reproduction. Then we will be in a better position to mitigate and rehabilitate impacts.

There is also need for more interdisciplinary approaches. The simultaneous consideration of more elements of the recreational environment would contribute to the development of synergistic insights and more realistic perspectives on management. We need both greater specialization within the natural sciences and more cooperation between natural and social sciences.

We need to expand regional coverage to parts of the country that have seldom been studied (almost any place other than the Sierra Nevada, Pacific Northwest, Northern Rockies, and Boundary Waters Canoe Area). Some of this research needs to be designed to be comparable with studies undertaken elsewhere. This would improve our current ability to assess the general applicability of research results. Other research should remain site specific. A good example would be research, modeled after the grazing research at Sequoia/Kings Canyon National Parks, to develop similar grazing management programs adapted to the unique situation of the area where the research is being done.

Many topics stand out as high-priority research needs. We clearly need an improved knowledge of wilderness ecosystems and their dynamics. This is important from the standpoint of evaluating our actions outside wilderness as well as improving wilderness management. Such information is important to the wilderness manager as a planning tool for evaluating likely consequences of management actions and as a picture of baseline conditions to be maintained.

Another major research need is information to improve management of both recreational and nonrecreational grazing. Neither is well understood within the context of an area with nature conservation goals like wilderness. Although both are permitted uses that detract from certain management goals, such conflicts can be minimized through research designed to tailor management to a given use and environmental situation. The Sequoia/Kings Canyon program (DeBenedetti and Parsons 1983) provides a good recreational grazing example, but no comparable domestic livestock example exists.

Along the lines of more traditional recreational ecology, top priorities include identification of use/impact relationships for varied ecosystem types, improved campsite design and/or maintenance practices, improved site rehabilitation techniques, improved recommendations for minimum impact camping, and more evaluation of management practices. Improved understanding of use/impact relationships could help identify use thresholds above which impacts become unacceptable. This information is needed to decide between requiring use of designated sites and allowing at-large camping, to impose use limits, and to attempt to direct use to resistant sites. This is particularly important in managing impacts in low-use portions of wildernesses where management emphasis is on dispersal and low-impact use.

Where use is concentrated on a few designated high-impact sites, design and maintenance techniques are needed to channel use and avoid site expansion. "Inter-site zones" need to be created and maintained, to be used as nurseries to replace overstory trees as they die. Experimentation with means of doing this should be a high priority. Improvement of site rehabilitation techniques is a closely related research topic. It is not clear, at this point, how much of this work can be generally applicable and how much is site specific or how much should be done by researchers as opposed to managers. What is clear is that we need both general and site-specific work and improved cooperation and communication between researchers and managers as well as between managers of different wildernesses.

I have mentioned the need for research on appropriate minimum-impact techniques a number of times in this paper. Although the value of recommendations such as not cutting down trees cannot be questioned, the advisability of certain fire building techniques is debatable. Moreover, the appropriateness of techniques varies between environments and between high-use and low-use situations. Improved knowledge, through research, could avoid problems of recommending inappropriate behavior and could tailor user behavior to different situations.

Finally, we should take advantage of the countless natural experiments that are taking place whenever management or use patterns change. We need to monitor change and evaluate the effectiveness of alternative techniques for minimizing impact.

The ultimate payoff of recreational ecology research to management is in efficient achievement of objectives. Impacts will never be eliminated, but both their distribution and their severity can be controlled and kept within acceptable limits. Actions taken to achieve objectives can be tailored to particular use and environmental situations that vary throughout the wilderness. To do this, however, we will need to finally make a serious investment in recreational ecology research, as we have in most other resource management disciplines.

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FISH AND WILDLIFE RESEARCH AND WILDERNESS IN THE UNITED STATES: A STATE-OF-KNOWLEDGE REVIEW

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ABSTRACT

A review of wildlife research conducted in the last 15 to 20 years in National Parks and wildernesses is presented to illustrate the close relationship between the two. Wilderness is essential for research on some human-avoiding species. Research is valuable to wilderness through identifying threats and ways to mitigate or avoid impacts of recreation, exotic species, pollution, and development activities. Research information can help predict the consequences of disturbances in these natural ecosystems and provide hope for their preservation.

INTRODUCTION

The National Park and Wilderness Preservation Systems were created to provide for the use and enjoyment of parks and wildernesses while leaving them unimpaired for future generations. However, the underlying motive was "to preserve something precious from a special standpoint which, when analyzed, proved to be based upon some natural phenomenon or other object of interest to scientists or historians" (Albright 1933). Later, the possible presence of "ecological, geological, or other features of scientific, educational, scenic, or historical value" was recognized as an attribute of wilderness (Public Law 88-577, Section 2.c.).

In 1872 when Yellowstone National Park was established, the objectives of providing for recreational use while preserving resources for future generations were not in serious conflict. Visitation was low, and the resource extensive. However, today the situation is far different. Park and wilderness areas are used by millions of visitors each year. Thus, balancing use and preservation of wilderness presents a serious dilemma for resource managers.

Fish and wildlife resources have been especially vulnerable to the pressures of human activities. Many of the species so often considered indicators of wilderness, such as the grizzly bear, wolf, and native cutthroat trout, have been negatively influenced by humans. Parks and wildernesses are also increasingly being influenced by activities outside their boundaries. Perhaps the most serious of these impacts is air pollution, but logging, livestock grazing, poaching, hydroelectric dams, and irrigation developments are other examples. Such impacts are of great concern because they not only impair resources for future recreational enjoyment, but jeopardize the value of wilderness as undisturbed reference areas for ecological research.

Thus, there is a symbiotic relationship between ecological research and wilderness. Research can help detect human-caused changes in wilderness ecosystems, as well as provide knowledge on which to base management programs. Wildernesses, on the other hand, are laboratories within which to study natural processes that are relatively free of human influence, and provide clean or undisturbed reference areas with which the health of managed ecosystems and landscapes can be compared (Franklin 1981).

In our review we have defined wilderness quite loosely, and included studies conducted in many areas that are not legally designated wildernesses. Much of the work described was done in National Parks or other relatively large and undisturbed natural areas. Furthermore, we generally restricted our review to studies conducted during the last 15 to 20 years.

This review is by no means comprehensive. Rather, our primary objective is to present representative examples of both basic and applied fish and wildlife research. Examples of basic research are those studies that have been conducted within parks or wilderness areas because of their uniquely undisturbed condition. Applied studies focus on research designed to monitor or mitigate human impacts on wilderness fish and wildlife.

OVERVIEW OF FISH AND WILDLIFE RESEARCH

We searched computerized data bases maintained by DIALOG Information Services for reference topics, such as fish and wildlife research in National Parks and wilderness. The primary data base searched was BIOSIS PREVIEWS, the online version of Biological Abstracts that contains over 4.5 million citations from more than 9,000 journals and monographs published from 1969 to the present. Additionally we searched AQUATIC SCIENCES AND FISHERIES ABSTRACTS, DISSERTATION ABSTRACTS, ZOOLOGICAL RECORD, CRIS (Current Research Information System)/USDA, and FEDRIP (Federal Research in Progress) data bases.

Search strategies varied among the data bases. For BIOSIS PREVIEWS, a large and relatively general data base, we conducted a hierarchical search that employed progressively more specific keywords. For data bases such as AQUATIC SCIENCES AND FISHERIES ABSTRACTS, this procedure was not necessary; these data bases were limited to a relatively narrow range of topics.

In general we searched these data bases for references that included "wilderness" or "national park" in the title

or as a major descriptor. Only those references were obtained for which the relationship to wilderness or National Parks was considered to be important. Although some potentially relevant references may have been missed, a large proportion of the published studies most likely to be of value to wilderness managers were probably found. Furthermore, we believe we obtained a representative sample of published research for our analysis of content.

In all data bases searched, references to National Parks far exceeded those to wilderness. For example, BIOSIS PREVIEWS contained approximately 2,000 references to National Parks compared to about 100 for wilderness. This imbalance probably results from a combination of factors. National Parks are frequently more accessible, have more logistical support, and have a longer research tradition than wilderness areas. Furthermore, "national park" may be more likely used in titles or keywords. Most references dealt with neither fish nor wildlife research. However, many studies provided important background information required to conduct or interpret research concerning fish and wildlife.

BIOSIS PREVIEWS was further searched to include only those references dealing with vertebrate ecology and either wilderness or National Parks. Of the approximately 140 references found, by far the most common taxa studied were mammals. They represented over 60 percent of the studies, with birds, fish, reptiles, and amphibians accounting for the remainder (fig. 1).

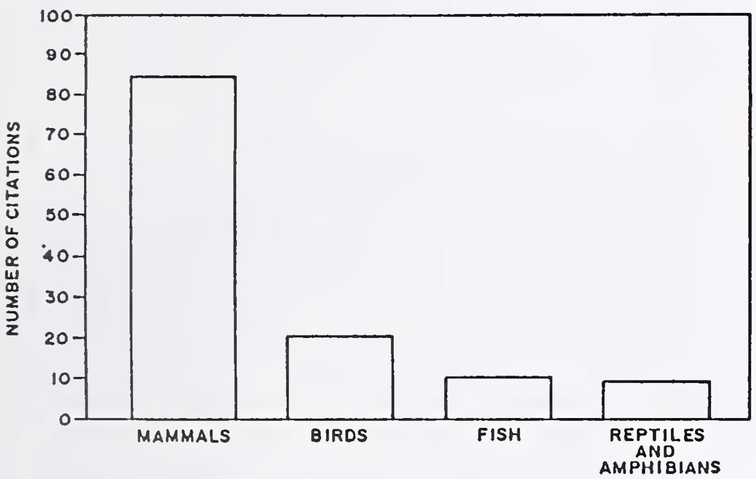

Figure 1.—Vertebrate taxa included in published studies dealing with National Parks or wilderness.

Because mammals were so well represented in the literature, vertebrate references from BIOSIS PREVIEWS were analyzed to determine which mammalian groups had been studied. Cervids (elk, deer, and moose) and small mammals were the most studied, followed by bears, feral pigs, and wolves (fig. 2). A search of the online version of ZOOLOGICAL RECORD, available only for the period 1978 through 1981, yielded similar results except that bears were the most studied group. The prominence of cervids, bears, and small mammals in mammalian research in National Parks and wilderness is probably related to the difficulty in studying more elusive and less abundant animals such as cougars, mountain goats, and wolverines.

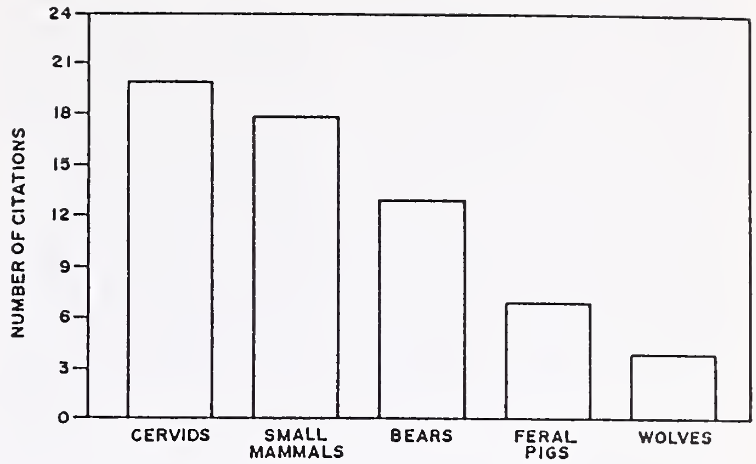

Figure 2.—Mammals included in published studies dealing with National Parks or wilderness.

Additionally, the role of native cervids and bears in park and wilderness ecosystems has historically been controversial and attracted the attention of both the scientific community and the public.

Thus for parks and wilderness, animal ecology research between the late 1960's and 1984 was heavily oriented toward terrestrial studies. Mammals were the most studied group, bird studies accounted for far fewer references, and studies of fish, reptiles, and amphibians were even less abundant.

BASIC RESEARCH AND WILDERNESS

Many wilderness areas in the United States have been classified as Biosphere Reserves with the primary objectives of conserving the biotic and genetic diversity of plants and animals within natural ecosystems, and providing areas for ecological research, with special emphasis on baseline studies. The following specific research priorities have been identified: (1) monitoring and research to improve understanding of the structure and function of ecosystems and their components; (2) determining environmental consequences of various land management practices; and (3) ensuring the effectiveness of biological reserves in preserving biotic and genetic diversity by consideration of size, habitat heterogeneity, and external influences (Franklin 1977). These objectives and priorities illustrate the importance of wilderness for ecological research, as well as for research on important ecosystem components such as fish and wildlife.

Wilderness and National Park areas have historically provided excellent study areas for wildlife research, and to a lesser extent for fisheries research. The desirability of these areas for research results from the absence of the effects of resource exploitation. Researchers have had the opportunity to study ecosystems that are relatively free from the influence of humans. The undisturbed nature of wilderness is becoming even more important as surrounding areas become progressively more developed and economically exploited.

Wilderness also provides the opportunity to study unthreatened species in an undisturbed environment. Some wildlife studies require extensive tracts of wildland

because of behavioral characteristics of certain species, such as large home-range size or sensitivity to disturbance by humans. In the United States, wilderness associated with National Parks has been especially valuable for these studies because hunting is generally not allowed (Franklin 1981). Information obtained from such studies improves the understanding of the fundamental ecology of these species, and may provide insights that are potentially valuable in managing these same species on nonwilderness lands. In many cases, park and wilderness areas serve as experimental controls with which to compare the effects of land management or development activities on adjacent or ecologically similar areas. The following studies illustrate the value of wilderness for basic research.

Ecology of Wolves

Natural regulation of populations is accomplished through a set of controlling mechanisms that limit or control populations in the absence of human influence (Peek 1980). Study of natural regulation must then be conducted in ecosystems in which predators, prey, and habitat are relatively free from human impacts, such as wilderness areas or National Parks.

Wolves and moose have been studied at Isle Royale National Park since 1958 (Mech 1966). During these years important insights into large mammal predator-prey relationships have been gained. For example, Peterson and others (1984) suggested that population fluctuations for moose result from long-term population cycles influenced by both physiological and environmental factors and that wolf population changes lagged behind similar changes in the moose population. The relationship between moose and wolf populations is complex because there are significant time lags in the various feedback mechanisms that tend to result in oscillations and overshooting of equilibria. It is clearly not a simple case of predator and prey reaching a stable equilibrium, with wolves regulating moose in some idealized textbook fashion, although Gasaway and others (1983) concluded that wolf predation can exert substantial control over prey populations under some circumstances.

Wilderness wolf research is of interest to wilderness managers and those interested in preserving the wolf. However, an improved understanding of the population regulation mechanisms influencing moose and other ungulates may also provide valuable information for use in managing hunted populations, as well as assessing the impacts of land management practices.

Ecology of Mountain Lions

Additional insights into predator-prey relationships for large mammals have been provided by studies of mountain lions in the wilderness of central Idaho (Idaho Primitive Area). Hornocker (1970) found that elk and deer populations were limited by food supply and lion predation did not directly determine numbers of elk and deer. However, he suggested that predation by lions dampens and protracts prey oscillations and helps distribute prey more evenly on critical ranges. Furthermore, he concluded that predation was an important evolutionary influence by removing less fit individuals from prey populations, and that this was of great significance in maintaining stability in a wilderness ecosystem.

Subsequently, Seidenstecker and others (1973) determined that the social behavior of mountain lions limited the density of breeding adults within the Idaho Primitive Area to a level below that which could be supported by the available food supply. Although resident lions did not totally exclude others, they occupied fairly distinct home areas. Individual isolation was maintained by avoidance, but the land tenure system was complex; individual relationships changed seasonally and varied between sexes and among age classes.

These basic studies have contributed greatly to an improved understanding of predator-prey relationships. They could only have been conducted in wilderness.

Wolverines and Wilderness

Because wolverines inhabit remote and relatively inaccessible areas, little is known of their population ecology. However, an extensive study of wolverines was conducted in the Bob Marshall Wilderness and adjacent areas of western Montana (Hornocker and Hash 1981). An important conclusion was that wilderness appears to be essential for the continued survival of wolverine populations. Wolverines separated themselves from humans by occupying steep and inaccessible areas during the summer when backcountry use was high, and moving to lowland nonwilderness areas only when snow limited human activity. Wolverines and wilderness users can apparently coexist. Hornocker and Hash concluded that with adequate wilderness habitat, viable wolverine populations should persist in Montana.

Ecology of the Olympic Elk

Throughout the Pacific Northwest, Roosevelt elk (*Cervus elaphus roosevelti*) are hunted, and presently occupy habitat that has been heavily influenced by logging, agriculture, and development. A notable exception is found in Olympic National Park where approximately 10,000 elk occupy undisturbed habitats and are not hunted legally. Excellent opportunities exist to study Roosevelt elk in these relatively pristine habitats.

For approximately the last 10 years, the social behavior, nutrition, and general ecology of these elk have been studied (Jenkins and Starkey 1982, 1984; Leslie and others 1984). This work suggests that elk occupying undisturbed habitats have a more stable and cohesive social structure than those inhabiting managed landscapes. Furthermore, considerable knowledge has been gained of the ecology of elk occupying old-growth forests. Much of this information is useful in assessing the impact of logging on elk populations, and would not be available if Olympic National Park did not exist.

Additionally, this study represents an example of work initiated as basic research, but for which an application arose. In 1983, two members of a neighboring Indian tribe were cited for illegally killing elk within Olympic National Park. Their legal defense involved alleged unextinguished treaty rights. Although the case was eventually won by the Park Service, the research was useful in assessing the potential impacts of tribal hunting on elk in Olympic

National Park. The only recent ecological information on which to base such an assessment had been obtained during the basic research. Clearly, there was not adequate time to initiate new studies.

APPLIED STUDIES AND MONITORING PROGRAMS

Designation or management as wilderness implies that natural resources will be undisturbed and affected only by natural processes. However, management activities and use by visitors often are significant sources of disturbance. Additionally, use and management of adjacent lands as well as anthropogenic changes in atmospheric conditions threaten wilderness ecosystems in many areas. The applied studies and monitoring programs that follow illustrate the role of research in maintaining undisturbed ecosystems in the face of increased competition for natural resources. Many of these examples seem to deal with a single species, such as the desert pupfish or grizzly bear, but actually describe changes in fundamental ecosystem processes. In fact, wilderness is influenced by a variety of internal and external factors. The examples also illustrate the diversity of threats to the integrity of wilderness ecosystems, and the regional and national scope of many of these problems.

Water Development

Because water is such a valuable commodity, particularly in the Western United States, wildernesses and National Parks frequently must compete for this resource with such uses as irrigation, power generation, and human consumption. Nonwilderness needs for water often have the highest priority, and wilderness is thus negatively impacted.

Impoundments.—The Colorado River drainages within Grand Canyon National Park, Canyonlands National Park, and Dinosaur National Monument have undergone extensive changes in hydrology and habitat since hydroelectric dams were built on the main river and its major tributaries (Dolan and others 1974). Research in these areas has documented the nature and magnitude of impacts on riparian and aquatic resources as a consequence of the environmental changes. For example, major alterations include drastic reductions in the frequency of flood peaks, an increase in diurnal discharge levels, decreased water temperatures and silt loads, and marked changes in alluvial morphology and vegetation patterns (Vanicek and Kramer 1969; Dolan and others 1974). These changes were followed by drastic reductions of native fish species, some of which are now endangered, such as the humpback chub (*Gila cypha*) (Holden and Stalnaker 1975). Recent studies suggest that depressed summer water temperatures render the main channel unsuitable for successful reproduction by several species (Kaeding and Zimmerman 1983). But changes in food abundance and type are also important. Reduced growth has been documented for the endangered Colorado squawfish (*Ptychocheilus lucius*) and the Colorado chub (*Gila robusta*) in the Green River downstream from Flaming Gorge Dam (Vanicek and Kramer 1969). The river conditions are so altered in some areas that only native fishes adapted to tributary streams are likely to survive (Holden and Stalnaker 1975). Additional threats include increased numbers and abundance of introduced species (Minckley and Binn 1976). It is difficult to document the impacts to native fishes from these species, but competition for food and space certainly influences native species.

Alteration of Water Levels.—Small populations of native fishes in isolated springs exist within the Death Valley drainage system. Habitat deterioration from removal of riparian vegetation, filling, installation of irrigation equipment in some springs, and general alteration of the water table through irrigation have affected water quality and altered water levels in many springs (Pister 1974). These changes have reduced the abundance of some populations and caused extinction of others (Minckley and Deacon 1968; Pister 1974). One such spring, Devils Hole in a detached portion of Death Valley Monument, is inhabited by the only natural population of the endangered Devils Hole pupfish (*Cyprinodon diabolis*). This situation serves as an example of the sensitivity of isolated populations to environmental changes.

Pumping of ground water from nearby wells decreased the water level in Devils Hole and reduced the amount of water on a rock shelf located near the surface of the spring. The drop coincided with a reduction in the population density of the pupfish. Later studies demonstrated that the shelf was an important feeding and spawning site for the fish (Minckley and Deacon 1973). In response to these findings, the National Park Service and the Nevada Department of Fish and Game suspended a fiberglass shelf beneath the pool surface to provide spawning area for the Devils Hole pupfish. Lights were suspended above the water to enhance algae production in 1970 (Pister 1974). Once the minimum water level was established by court order in 1977, the shelf was removed and lights turned off, but both were left at the site for use in an emergency. In 1972, 27 fish were transferred to an artificial refuge downstream from Hoover Dam. These fish have reproduced but appear to have different body size and other meristic features from the original populations (Pister 1974).

A recovery plan for the Devils Hole pupfish was completed in 1980. The plan describes needs for enforcement; habitat control; monitoring physical, chemical, and biological components of the spring system; maintenance of the Hoover Dam refugium and establishment of another; determination of the factors controlling the population size of the pupfish; public education; and restoration and maintenance of natural conditions. These objectives require a great commitment of time and effort and illustrate the importance of research for preserving even an isolated fish population.

Some large areas like Everglades National Park (6,000 km^2) also have serious native fish problems as a result of alterations of natural hydrologic cycles. The problems at Everglades National Park developed from major alterations of the hydrological systems throughout southeastern Florida by an extensive canal and levee system managed to meet agricultural and urban needs. Research has shown that the system has changed from the original continuous marsh to a series of impoundments designed to

release water during flood conditions and impound or divert water during drought. Impacts from these external management actions have major impacts on the park's aquatic habitat, ranging from the dispersal of native fishes and nest failure of wading birds to extensive mortality of fishes during droughts (Loftus 1985). Furthermore, the persistence of abnormally high water over several years in localized areas has caused the fish communities to undergo changes from a marsh to a more lakelike structure (Kushlan 1985). Present research studies are defining the relationships between water conditions and the structure of the freshwater community in the park.

Fluctuating water levels are also a problem in Voyageurs National Park, northern Minnesota. Dams on Rainy Lake and the creation of Namakan Reservoir have greatly altered the hydrologic regime. The Namakan Reservoir is used to buffer the level of Rainy Lake for maximum power generation. This results in greater than natural fluctuations for the Namakan Reservoir, and less than natural fluctuations for Rainy Lake. Also, the pattern of seasonal change has been altered. Fish, wildlife, and littoral plants in the lake have been impacted. A multidisciplinary study has been initiated to assess the relationships between natural and altered fluctuations and develop alternative strategies to minimize human-caused impacts on fish and wildlife populations (Kallemeyn 1983).

Introduced Wildlife Species

Many nonnative and exotic wildlife species have been introduced to wilderness areas of the United States. Some were introduced to provide hunting opportunities; others originated from domestic livestock or escaped pets. Some of these species, such as European wild boar, wild horses, and wild burros, are truly exotic, while others are native to other areas of North America. For example, mountain goats, elk, and wild turkey have all been transported to areas where they are not indigenous. Exotics can greatly influence ecological processes including predator-prey and plant-herbivore relationships, and energy cycles (Goigel and Bratton 1983). The following examples illustrate the use of research to identify the impacts of introduced animals as well as provide a basis for mitigation actions.

Wild Pigs.—True swine (Suidae) are not native to North America (Singer 1981), but arrived with Spanish colonists in the early 16th century. Colonists continued to bring pigs, many of which escaped and served as a source for a feral pig population which spread throughout the Southeastern United States and portions of California by the early 1900's. Presently, wild pigs inhabit 13 areas of the National Park System (Singer 1981).

European wild boar escaped from a hunting preserve in North Carolina in 1913 and are now abundant in Great Smoky Mountains National Park (Goigel and Bratton 1983). The number of wild boar inhabiting Great Smoky Mountains is unknown, primarily because of difficulties involved in censusing the species. However, the population has been estimated at about 1,500 animals found throughout most of the park (Tate 1984).

Wild boar have been responsible for significant changes in the Great Smoky Mountains ecosystem. Hog rooting, feeding, and trampling have greatly influenced forest understory communities (Bratton 1975) and through habitat alteration have the potential for negatively affecting other animal species (Tate 1984).

The basic biology of both European wild boar and feral pigs is now well understood, but information on population estimates, impacts, and management strategies is inadequate. Furthermore, because pig densities, impacts, and response to reduction programs vary greatly among areas, research is required to provide area-specific management information.

Mountain Goats.—Although mountain goats (*Oreamnos americanus*) are native to the Cascade Mountains of Washington, there is no historical evidence of their presence on the Olympic Peninsula prior to their introduction by hunters between 1925 and 1929 (Moorhead and Stevens 1982). At the time of introduction, much of the Olympic Peninsula was managed as a national monument by the U.S. Department of Agriculture, Forest Service, and hunting was allowed. Hunting was subsequently prohibited when the National Park Service assumed management responsibility for the area in 1933. By 1983, goat densities in portions of Olympic National Park were the highest in North America (Stevens 1983), and the total park population exceeded 1,000 (Houston and others 1986).

A program has been established to monitor vegetation impacts of mountain goats in Olympic National Park. However, this has been difficult because no quantitative information exists on vegetation prior to the introduction of goats. Comparison between areas of high and low goat density is not possible because of fundamental ecological differences (Houston and others 1984). These difficulties have been encountered in virtually every area where the impacts of exotic wildlife species have been studied.

Additional research has been conducted on census methods and capture and removal techniques. During 1981-83, 50 to 60 goats were trapped and removed each year from a single area (Klahhane Ridge), and an increased effort was made during the summer of 1985 to remove goats by live capture utilizing helicopters. Future research will focus on the response of mountain goat populations and plant communities, so that effectiveness of management actions can be evaluated.

Introduced Fish

There has been a long history of widespread stocking of native, nonnative, and exotic fish species into lakes and streams in remote areas now designated as wilderness. Concern, first voiced by early fisheries biologists (King 1937), about the potential damage to native gene pools from such plantings continues today. In fact, great care is required when selecting brood stock for supplementation or enhancement of native fish populations. Recent evidence indicates that significant genetic differences can occur between native stocks that could influence reproductive success, even if populations are not separated by great distances (McIntyre 1984).

Introductions of exotic fish species have often coincided with negative changes in native populations. Impacts of exotic fishes include alterations of habitat, introduction of new parasites and diseases, trophic changes, hybridization, and altered spatial relationships (Taylor and others 1984).

Introduced species are most successful in simple communities with low diversity of native species (Minckley and Deacon 1968), in disturbed sites (Taylor and others 1984), or in lakes naturally barren of fish.

Interactions between introduced species and native species may be minimal but these situations still compromise the native; habitat partitioning often results (Nilsson 1967). In other cases the interactions may be great enough to cause or contribute to the extinction of a native species, especially those with limited indigenous ranges such as desert spring fishes, or drastically reduce their distributions, enhancing isolation (Minckley and Deacon 1968). Research results do not support contemporary views favoring the introduction of nonnative and exotic fishes into wilderness areas. Long-term impacts on native fishes are a primary concern.

Native and Introduced Cutthroat Trout.—A genetic reconnaisance of native westslope cutthroat trout (*Salmo lewisi clarki*) was recently completed in lakes of Glacier National Park (Marnell 1981). The purpose of the study was to document the genetic composition of native populations after millions of nonnative Yellowstone cutthroat trout (*Salmo clarki bouvieri*) had been planted from 1912 to the late 1960's. Marnell discovered that pure populations of *lewisi* still exist. He also discovered, however, that some lakes contained westslope-Yellowstone hybrids and others (naturally barren lakes) only *bouvieri*. Despite extensive stocking programs, Marnell concluded that selection pressures appear to favor the native over *bouvieri* in most cases. Nonetheless, part of the gene pool of the native subspecies has been lost through hybridization.

Varley (1979) described the status and ecology of the Yellowstone cutthroat trout and the Snake River finespotted cutthroat trout (*S. clarki* subsp.). The two subspecies still occupy significant portions of their native ranges and possess great genetic and behavioral variability as illustrated by their wide range of spawning seasons, spawning sites, fry emergence behavior, feeding behaviors, and specific habitats. These adaptations represent different ecotypes. Varley argued that management of these ecotypes will maintain the genetic variability of the indigenous gene pool and supported a registry of the ecotype varieties.

These studies are good examples of how research can be used to identify the existence of native gene stocks. Such information offers managers a better understanding of the diversity and status of natural resources that can make important contributions to management's strategies, policies, and actions.

Native Brook Trout and Introduced Rainbow Trout.—From early in this century until about 1937, about 60 percent of the area now in Great Smoky Mountains National Park was logged (White 1980). Logging and related activities greatly deteriorated stream water quality. These conditions plus heavy fishing pressures resulted in drastic declines in the abundance of native brook trout, especially at the lower elevations where the disturbances were most intense. Nonnative rainbow trout were stocked in the disturbed reaches and to a limited extent at higher elevations from logging railroad trestles. Stocking continued at the lower elevations of many park streams into the 1960's by the National Park Service. Studies by King (1937), Lennon (1967), and Kelly and others (1980) showed that the rainbow trout have done very well and, in fact, have extended their distribution by immigrating upstream into remnant brook trout populations in unlogged portions of the watersheds. This expansion coincided with further reductions in the range of brook trout. In fact, most brook trout populations now occupy short sections of small tributary mountain streams high in elevation and gradient (Larson and Moore 1985).

Continued encroachment by nonnative rainbow trout stimulated two research studies. The first was an assessment of the population structure of each species at different stages of encroachment. The results supported the hypothesis that interaction with rainbow trout is a major reason for the continued decline of the natives (Larson and Moore 1985). The second was an experimental study to assess the feasibility of eradicating sympatric rainbow trout from four remnant brook trout populations in 1976. Although chemical treatments had been used years earlier in the park to eradicate rainbow trout (Lennon and Parker 1959), backpack electrofishing was the only technique allowed at the time of this work. Rainbow trout populations were greatly reduced, but not eradicated, after up to 6 years of electrofishing (Moore and others 1983). Recovery rates of the brook trout populations differed between streams, but reached maximum densities by the end of the study (Moore and others 1986). Additional work will be required to determine the long-term effects of electrofishing on the rainbow trout-brook trout relationships. Nonetheless, this research demonstrated that the electrofishing technique was useful for population control, but not eradication. It also showed that brook trout increased in density after removal of the rainbow trout, providing additional support for the hypothesis that rainbow trout have a negative impact on brook trout.

Wild and Hatchery Salmon Stocks.—Management of wild fish stocks on Washington's Olympic Peninsula is controversial and complex, largely a result of conflicting interests of various management agencies and user groups. However, a number of studies have been conducted (Walton and Houston 1984), and research will undoubtedly play an important role in future management planning.

Substantial populations of anadromous fish utilize Olympic National Park during portions of each year. Most of these populations are heavily harvested outside park boundaries by commercial and sport fishing on the lower reaches of the rivers, or at sea. Recreational fishing is also allowed within the park (Houston and Contor 1984).

Large numbers of hatchery fish are introduced to several of the rivers annually, and a major proportion of the harvest consists of these introduced fish. The hatchery stocks have been derived from both native local stocks and those transferred from other areas. There is a potential for alteration of the genetic makeup of existing wild stocks, but it is unclear how effective hatchery stocks are in spawning in the wild. Wild stocks may also be negatively influenced by competition with hatchery juveniles for resources, but more commonly wild stocks are impacted as a result of the high harvest rates imposed on hatchery stocks (Houston 1983). Hatchery coho stocks may be harvested at rates up to 95 percent, compared to the 60- to 75-percent harvest that can usually be sustained by wild stocks (Wright 1981).

Changes in Atmospheric Quality

Although wilderness areas are usually remote from industrial and urban areas of the Eastern United States, wilderness fish and wildlife are nonetheless exposed to air pollution and acid rain, because many pollutants travel long distances (Cowling and Linthurst 1981). Also, wilderness areas of the Western United States may be influenced by acid rain resulting from automobile emissions in urban areas (Glass and others 1981).

Impacts of Acidic Atmospheric Deposition.—Acidic atmospheric deposition has tremendous potential for impacts on aquatic ecosystems in general, and especially areas where lakes and streams are low in alkalinity (Glass and others 1981). Acidification of atmospheric deposition results from pollutants (especially oxides of nitrogen and sulfur) from industry, metal smelting, and combustion of fossil fuels (Haines 1981). Regions in North America with low capacities to neutralize these acidic inputs have shown decreases in stream and lake pH and increased concentrations of metals, especially aluminum (Haines 1981). Impacts to aquatic systems from these changes in water quality can extend to all trophic levels; but the impacts are variable, depending on the species involved, pH, concentration, and type of metal (Schindler and others 1985). In some cases the conditions can be acutely toxic to fishes (Schofield 1976). Less severe conditions can lead to death of a population through loss or reduction of reproduction, to reduced growth (Beamish 1974), and to skeletal deformities (Beamish 1972). Because large areas of the United States are considered moderately to highly sensitive to acidic atmospheric deposition, and because about two-thirds of the land area is receiving such inputs (Cowling 1982), the potential for impacting fish populations in wilderness areas is quite high.

Lakes in the Adirondack State Park of New York, the Boundary Waters Canoe Area-Voyageurs National Park of Minnesota, and Nicolet National Forest of northern Wisconsin are especially sensitive to the effects of acid precipitation (Glass and others 1980). In the Adirondack area, pH values have declined to such a low level that approximately 100 lakes are fishless (Schofield 1976). In northern Minnesota and Wisconsin lake acidification is just beginning, but the annual average pH of precipitation in the region is approximately 4.6 and the potential for ecological damage is great (Glass and others 1980).

Impacts of acid rain are not restricted to fish, but relatively little research has been conducted to document the response of other wildlife species. Bird species such as loons, ospreys, and blue herons, that depend on aquatic organisms for food, may be especially vulnerable (Loucks 1980).

Many western lakes, streams, and soils are potentially sensitive to acidification. Acid rain is common in the Cascade Mountains of Washington and the Sierra Nevada Mountains of California (Powers and Rambo 1981). For example, the North Cascade Mountains of Washington receive precipitation with pH values as low as 4.0 (Powers and Rambo 1981). The potential for ecological damage from acid rain is not restricted to the eastern portion of the United States. Many large western wilderness areas are likely to be impacted in the future.

Air Pollution.—In addition to pollutants that cause acidification of precipitation, trace elements, metals, nonmetallic ions, organic compounds, radioactive particulates, and photochemical oxidants such as ozone can have both lethal and sublethal effects on fish and wildlife (Newman and Schreiber 1984).

Unfortunately, there have been few studies of the effects of such pollutants on fish and wildlife of wilderness areas. However, anthropogenic inputs of polychlorinated biphenyls and trace elements have been described for remote lakes of Rocky Mountain National Park (Heit and others 1984) and elevated lead levels have been reported for forest litter in Great Smoky Mountains National Park (Wiersma and Brown 1980). Concentrations of heavy metals and sulfur in subalpine fir and lichen are higher in Mount Rainier National Park than in these species in Olympic National Park; this suggests that prevailing westerly winds transport pollutants to Mount Rainier from the Seattle-Tacoma metropolitan areas (Frenzel and others 1985). Research is currently under way to determine whether wildlife in these two parks also have differing tissue concentrations of these elements.

Impacts of Recreational Use

With increasing use of wilderness areas, the potential for conflicts between humans and wildlife has also increased. Wildlife is exposed to a variety of disturbances, ranging from harassment to the mere presence of humans. In general, humans were not an important selective factor in the evolution of most wilderness wildlife species. Thus, even low-level exposure to humans may cause significant changes in their behavior and distribution.

Recreational impacts on fish and wildlife are part of the dilemma of providing for use and enjoyment while preserving wilderness resources for future generations. However, human impacts on wilderness wildlife are often subtle and difficult to measure. Animals may avoid humans by changing their spatial distribution or restricting activity to periods of low human disturbance such as evenings or early mornings. Alternatively, they may become habituated to the presence of humans and even learn to obtain food from them. In either case, the naturalness of the wilderness ecosystem is compromised.

Grizzly bears and common loons are generally considered to be wilderness species, and both inhabit areas that receive intense recreational use. The following discussion of these two species illustrates the difficulties in determining impacts of wilderness users on wildlife in general, as well as the need for research to develop mitigating measures.

Grizzly Bears and People.—Conflicts between bears and backcountry users are especially serious because of the likelihood of personal injury or property damage. Because of concern for public safety, injuries and fatalities from grizzly bear attacks frequently trigger proposals to eliminate bears from areas such as National Parks (Moment 1969, 1970). Clearly such actions would be contradictory to the fundamental purposes for protecting wilderness.

Management of wilderness areas inhabited by grizzly bears has thus commonly focused on strategies to allow coexistence with humans (Jope and Shelby 1984). In most

areas, these strategies have been successful. In Glacier National Park from 1910 to 1982, there were 24 grizzly bear-visitor confrontations resulting in 27 injuries and six deaths. Most of these confrontations occurred between 1951 and 1982, and the number of confrontations was highly correlated with park visitation. During this time, total visitation ranged from nearly 7 million for the decade of the 1950's to over 12 million in the 1970's (Martinka 1982). Apparently the probability of individual visitors being confronted by grizzly bears did not change significantly during this period.

There is growing concern about possible changes in grizzly bear behavior resulting from exposure to humans. Research suggests that grizzly bears' wariness of people has recently declined in some areas through habituation (Jope 1985). The influence of habituation on incident and injury probabilities is uncertain. Loss of fear of humans could increase risk of hiker injuries (Martinka 1982; McCullough 1982) or in some circumstances reduce the likelihood of charges by grizzly bears (Jope and Shelby 1984), especially if backcountry users behave in a predictable fashion by remaining on trails, not traveling at night, and wearing "bear bells" (Jope 1985).

Further research is needed to provide managers with information required to ensure grizzly bears and humans can coexist in wilderness areas. Perhaps the easiest solution is to close areas of high grizzly density to backcountry users, or to use computer models to identify travel patterns that would minimize the risk of encounters with grizzly bears (Stuart 1978).

However, some wilderness users believe that exposure to danger is part of a wilderness experience. There is an important philosophical question involved in restricting visitor use for safety purposes, but encounters with grizzly bears clearly represent more than a hazard to backcountry users.

From 1973 through 1983, 31 known mortalities of adult female grizzly bears occurred in Yellowstone National Park and the adjacent area (Knight and Eberhardt 1984). About one-third were killed by government agents or individuals in self-defense or to protect against property damage. Significant numbers of deaths are not reported (Blanchard and Knight 1980). Because the reproductive rate of grizzly bears in the area is low and declining, the population is sensitive to loss of reproductive-age females. The difference between continued decline and population stability in the Yellowstone area may be as few as one or two bear mortalities a year (Knight and Eberhardt 1984). Therefore, human-caused mortalities must be kept to a minimum and careful monitoring of grizzly bear populations will be critical.

Common Loons and Recreational Use of Wilderness.— Common loons are summer residents of lakes in the boreal forest areas of northern North America. Recreational use of these lakes has increased greatly during recent years. For example, from 1950 to 1976, visitation to the Boundary Waters Canoe Area of the Superior National Forest increased eightfold (Titus and VanDruff 1981). Increased recreational use may be responsible for many nest failures of common loons in this area (Ream 1976).

Titus and VanDruff (1981) concluded that there was little or no effect of heavy recreational use on loon productivity, and suggest that loons may be habituating to the presence of humans. From 1951 to 1976 when recreational use increased greatly, loon populations increased by about 35 percent. However, some negative effects of human use were documented. Loons on lakes where motors were allowed were less successful in hatching eggs than those on lakes where motors were prohibited. Also, loon pairs nesting near areas of intense human use produced fewer surviving young than those exposed to fewer human contacts.

As for grizzly bears, additional research is required to more fully understand the response of common loons to increased wilderness use. Further research on habituation is extremely important because it may be possible to reduce behavioral impacts by gradually increasing recreational use to allow loons an opportunity to habituate to humans. However, the desirability of habituation of wilderness wildlife to humans is uncertain.

Impacts of Fishing.—Although hunting is generally not permitted in National Parks, fishing has historically been a popular activity in many parks, and is commonly allowed in wilderness areas. As a result of increasing angling pressure, management of fish populations has become an important activity in many park and wilderness areas.

Yellowstone National Park is famous for its fishery resources (Varley and Schullery 1983) and provides a good example of the challenges faced by managers in providing a quality recreational experience and maintaining natural fish populations. Fishing pressure has been heavy throughout the history of the park. A variety of management techniques have been applied, ranging from no size or creel limits to a "catch and release" policy (Varley 1984). The response of the lake and stream fish populations has been variable, reflecting the complex relationships among the environmental conditions, the ecology of fish species, and fishing pressure. The two studies that follow were designed to monitor the effects of changes in fishing regulations.

Very soon after the establishment of Yellowstone National Park, heavy fishing pressure began to negatively influence the native cutthroat trout in Yellowstone Lake. Between the 1880's and late 1960's several regulations were imposed on the fishery to protect the resource (Gresswell 1980). In the 1970's, a 356-mm (14-inch) minimum size limit was instituted, and although there was an initial improvement in the fish population, an increase of effort and harvest decreased the abundance of the larger classes in the fish population. A major change in the regulations was made in 1975 when a 330-mm (13-inch) maximum size was imposed. Larger fish have become more abundant, even though angling success has increased (Gresswell 1983). Long-term studies are required, however, to evaluate the results of these changes in regulations (Gresswell 1980).

Yellowstone River has been a popular fishing area also. Numerous regulations were applied in attempts to protect the native cutthroat trout in the river, but these were not successful (Varley 1984). In 1973 a "catch and release" regulation was adopted. This resulted in an initial drop in angler use, probably caused by factors such as dispersal of anglers and decreased park visitation. However, use increased in subsequent years and by 1981 it exceeded that

prior to the "catch and release" regulation. The average age and length of fish have increased and angler satisfaction seems to be high (Varley 1984).

Genetics and Wilderness Management

The survival of any species depends on its having enough genetic diversity to respond to new selection pressures resulting from changes in its environment. An important variable that influences genetic diversity is the area of habitat available to given species. Larger areas typically have greater habitat heterogeneity and support greater populations with greater genetic diversity than smaller areas (Schonewald-Cox 1983).

There has been considerable concern over the adequacy of existing parks and wildernesses to support existing species over the long term. Since the 1970's a number of research studies have been published that deal with the biogeographic similarities of protected reserves and islands, and examine species-area relationships for large mammals. Much of the work has been done outside the United States, but may be applicable. Apparently, most existing reserves are too small to maintain certain animal species indefinitely (Schonewald-Cox 1983). This may be especially true for large herbivores and carnivores; some forms of genetic management may be necessary to preserve some of these species. Schonewald-Cox (1983) has developed initial guidelines for management of genetic diversity in parks or reserves but further research will be required as a basis for wilderness planning and management.

FUTURE RESEARCH NEEDS

Most ecological research in wilderness and National Parks has been terrestrial in orientation. This may be related to management needs or reflect a historic preoccupation with the study of mammals, and to a lesser extent birds. This emphasis is likely to continue because of the value of reserves in the preservation of large mammal species such as wolves and bears.

While terrestrial studies will continue to be important in managing and preserving wilderness, there are many potential threats to aquatic wilderness ecosystems such as fishing, exotic species, and acid rain. Increased emphasis must be placed on aquatic research in parks and wilderness so that changes in aquatic ecosystems can be detected and interpreted in a timely fashion. It should also be recognized that aquatic systems are only parts of watersheds and must be considered in the broader context (Warren 1979; Vannote and others 1980). Greater understanding of the relationships between aquatic systems and watershed processes is needed (Lotspeich and Platts 1981; Everest and Sedell 1983).

Fish and wildlife research will play an even more important role in wilderness management for the foreseeable future. Both increasing visitor use and growing external threats will challenge our ability to maintain the integrity of these relatively undisturbed ecosystems, and management decisions must be based on an increasingly sophisticated understanding of wilderness ecology.

Managers have already become more dependent on ecological information. For example, decisions to control exotic animals such as feral pigs or introduced mountain goats can no longer simply be based on arbitrary agency policy. The public demands scientific support for such management decisions; ecological damage must be demonstrated. This trend is likely to continue in the future.

Cooperation between social and biological scientists will be especially important in developing wilderness use plans that optimize fish, wildlife, and recreational values. Visitor use will continue to be potentially threatening to wilderness wildlife. However, we believe that recreational impacts on wilderness can be more easily mitigated than impacts from extramural sources. Although demand of wilderness recreation is likely to remain high, this can be readily managed by such means as restricting access, establishing limits on backcountry use, or even by closing areas. However, decisions to constrain the public use of these areas must be based on sound information, which in many cases can only be obtained through research.

Unfortunately, thorough research cannot be hurried. Wilderness research needs must be identified well in advance of anticipated problems, or managers must be willing to implement interim management policies until more information is obtained. Thus both basic and applied fish and wildlife research must be encouraged.

The understanding of ecological processes that can be obtained from basic research is especially important in assessing and documenting human-caused changes in wilderness. Unless we first understand the natural processes and dynamics of wilderness ecosystems, it is impossible to determine cause and effect relationships.

Ecological research must be more systems oriented. Study of single species or narrowly defined natural communities will continue to be important (Hornocker 1978), but a broader perspective will be required to understand and preserve wilderness ecosystems.

In many areas, synthesis and analysis of existing information will be of more value than the initiation of new field studies (Wright and Hayward 1985). Models will play an increasingly important role in the identification of information gaps, as well as prediction of the consequences of both natural and human-caused disturbance of wilderness ecosystems (Houston 1982).

We believe that only through research can we hope to preserve parks and wilderness from the many threats presently impinging on them. Difficult social and political choices lie ahead, and these decisions must be based on high-quality information obtained through research.

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WATER RESOURCES RESEARCH FOR WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

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ABSTRACT

The state of knowledge regarding watershed science as applied to wilderness or as related to the wilderness preservation concept is viewed relative to development of a strategy for implementation of long-term watershed studies. The substantial body of water resources research is applicable to understanding wilderness water management questions. Existing knowledge about issues of health and safety, technological development, visitor use, or ecological change is related to the need for new baseline knowledge about the consequences of various land-use activities. Impediments to wilderness research (access, measurement difficulties, experimental design), although considerable, are not overriding, particularly as our perception of consequence increases. The recommended approach to wilderness water resources studies, built on experiences borrowed from the National Park Service, National Science Foundation, and the U.S. Forest Service, requires establishment of a system of long-term watershed research sites. Implementation of this program ensures common measurements of physical, chemical, and biological parameters within the biosphere and hydrosphere, and of necessity includes sampling of precipitation, climate, soils, vegetation, and aquatic variables.

INTRODUCTION

Management strategies, to effectively protect the water resources in wildernesses, must be based on an understanding of the physical, hydrologic, and biologic processes which are actively shaping these systems and an appreciation of the potential for impact of various land-use activities on the water resources. Water resources, whether flowing or standing, represent an integration of the combined effects of all activities within the watershed. It is for this reason that researchers theoretically are able to look to the water resources to quickly determine the state of health of the entire watershed or ecosystem.

The purpose of this paper is to provide a brief overview, with examples of pertinent studies, of the state of knowledge about water and watershed science relevant to the wilderness setting and the wilderness preservation concept. The intent is to provide wilderness managers with an overview of existing water quantity and quality research knowledge and with a strategy for implementing long-term watershed research.

Since wildernesses are managed to preserve their wilderness character, land-use activities are generally restricted to recreation use such as hiking, skiing, backpacking, trail riding, and fishing; mechanized means of transport are generally prohibited. Although natural catastrophes, for example landslides and lightning-caused wildfire, can have serious impacts on the water resource, most past water resources concerns in wildernesses have centered on recreational use: protecting the health of the user and quantifying user impacts on water quality.

There is a substantial body of research that examines the effects of recreation on various attributes of wilderness, and on water resources. However, little research has specifically examined the effects of recreation on wilderness water resources. Therefore, much of what is presumed known about wilderness water resources is determined by analogy from studies in nonwilderness areas.

The most obvious reason for the paucity of water research in the wilderness setting is access. The very nature of wilderness connotes remoteness and isolation. While not all wildernesses are located in high, difficult-to-access mountain areas, most are generally rugged and remote. Further, access to research sites is difficult due to the limitations on use of modern technology and mechanized transport. Access can be more than just a difficult business causing discomfort to the researcher; it can also be personally hazardous. During the winter, access to certain mountain areas is often ill advised or virtually impossible.

A second reason for the lack of wilderness water research lies in the nature of resource impacts. It is often difficult to discriminate effects from background water quality levels. This complicates statistical analysis and limits the opportunity to infer statistically valid cause-effect relationships. The level of effect to be measured is often so small that measurement science is forced to its limits of detection. At this end of the detection spectrum, specific detailed steps are often required in the collection, transport, and measurement of certain variables. The necessary steps are often difficult and sometimes impractical or impossible in a wilderness setting.

A third reason for the lack of research may be found in the magnitude of consequence. Often, while an effect may be suspected or even measured, the consequence is not thought to be great or it presents no immediate hazard to either the visitor or the ecosystem.

A fourth reason is that there is limited opportunity for controlled experiments in the wilderness. Experimentation requires the deliberate manipulation of at least one variable affecting the system under study. Clearly, the influence of man is intentionally manifested in such an effort and to that degree it runs counter to the wilderness philosophy.

There are without doubt other reasons that could be enumerated for the lack of water resources research in wildernesses. However, these four reasons are likely the principal ones.

In view of the reasons listed, it is not surprising that water resources research techniques unique to the wilderness setting have not evolved. Most research efforts have been directed at using high-technology, lighter, portable (low power demand) equipment and obtaining data with as few site entries as possible. Often the development of technology limits the utility of the data collection. This is not to say that no suitable research techniques are available. Many research techniques have been developed and relationships established that can be and are profitably used in the wilderness setting; however, they were generally the result of studies in nonwilderness areas.

Similarly, a substantial body of research literature has been developed from studies of the effects on the water resource of industry; mining, milling, and minerals exploration; timber harvest, forest fertilization, road construction, and other silviculture-related activities; and hydropower, irrigation, and other water resource developments. Many of these studies have applicability to the wilderness setting, both in research techniques used and in relationships developed.

This body of knowledge, coupled with the research conducted in wilderness or wildernesslike environments, provides a broad understanding of the resource and a general understanding of its behavior. Perhaps more importantly it adds some insight into deficiencies in our understanding and identifies areas of additional research needs.

OVERVIEW OF PAST STUDIES

For the purposes of this overview, issues related to health and safety, technological development, visitor use, ecological change, and baseline understanding are emphasized. Impacts are thought of as internally or externally derived consequences, either direct or indirect, of recreationist activity, wildlife behavior, wildfire, anthropogenic, and certain natural biologic, hydrologic, and geologic processes.

The majority of existing water studies in wilderness and wildernesslike settings are associated with recreationist health and safety. This is not surprising because of the magnitude and perception of and immediacy of the potential impact, and the relative ease with which impacts may be identified. A number of studies have focused on the polluting effects of human and animal fecal disposal and increased contamination due to increased intensity of human use (Johnson and Middlebrooks 1975; Knudsen and others 1977; Christensen and others 1979; Varness and others 1978; Howard and Stanley-Saunders 1979).

Much of what was learned about water quality contamination in other areas is directly applicable to wilderness situations. The concern for health and safety has been elevated in recent years with the increase in either the incidence or the diagnosis of giardiasis. *Giardia* sp., a flagellated protozoan that inhabits the intestinal track of numerous mammals, causes gastrointestinal distress in humans. Of particular interest is illness associated with the consumption of untreated or poorly treated water in backcountry settings (Grant and Woo 1978; Black and others 1978; Craun 1979; Davies and Hibler 1979; Williams 1981; Suk 1983).

Studies of the health and safety aspects of wilderness water sources have not resulted in unequivocal answers; in fact more questions may be raised than are answered. Often we do not understand the natural environment well enough to evaluate our results. This has led to many studies of bacterial levels in areas with and without the influence of man (Bissonnette 1971; Stuart and others 1971; Walter and Bottman 1967; McFeters and others 1978; Erman 1979; Silverman and Erman 1979; Dasher and others 1981).

The remaining uncertainties suggest the need for studies of indicator bacteria themselves. Numerous studies have confirmed the large variability of bacterial organisms and have led to better understanding of animal and human contamination (Hendricks 1971; VanDonsal and Geldreich 1971; Skinner and others 1974; Geldreich 1976; Matson and others 1978; Varness and others 1978; White and others 1978; Grimes 1980; Gary 1982; Skinner and others 1984; Tunnicliff and Brickler 1984).

A subset of man's uses of wilderness is domestic livestock grazing. Studies have demonstrated that increased levels of bacteria can be associated with the presence of cattle (Kunkle and Meiman 1967; Kunkle 1970; Milne 1976; Stephenson and Street 1978; Skinner and others 1984), and that health hazards arise from livestock contamination (Willrich 1967; Diesch 1970; Swanson 1977). However, such contamination has been found to be short lived following discontinuation of grazing (Milne 1976).

The importance of human contributions to eutrophication is also recognized. Studies have been concerned with the potentially adverse impacts to dissolved oxygen and the nutrient content of a number of highly used wilderness lakes in the West (Barton 1969a, 1969b; King and Mace 1974; Erman 1979; Silverman and Erman 1979).

Other water resources impacts have received less attention in the wilderness context but are no less consequential. The effects of wildfire on water resources are an example. Wildfire can obviously be either natural or human caused. Further, management (suppression, control, or prescribed fire) can affect its consequences in the aquatic ecosystem. Fire research is not discussed here; however, a number of water resources impacts can be cited (Meginnis 1935; Copley and others 1944; Colman 1953; Rowe and others 1954; Sinclair and Hamilton 1955; Krammes 1960; Crouse 1961; Glendening and others 1961; Rich 1962; Krammes and DeBano 1965; Pase and Ingebo 1965; DeBano and Krammes 1966; DeBano and others 1970; Berndt 1971; Brown 1972; DeByle and Packer 1972; Helvey 1973; Rice 1974; Anderson and others 1976; Dyrness 1976; Helvey and others 1976; Wright 1976; Wright and others 1976; Campbell and others 1977; Davis 1977). The duration of these effects has been shown to vary substantially. Changes in summer water temperatures, streamflow, and mineral export were identified in a stream draining a

watershed burned 45 and 36 years previously (Albin 1979). Only minor changes in the hydrology, chemistry, and phytoplankton biology of a wilderness lake were noted using paleolimnologic techniques 2 years after the watershed was burned (Bradbury and others 1975).

Mining activities occurring in areas prior to their declaration as wilderness can have latent potential effects. Some of the national parks in Alaska have active mining operations. Austin and Munteanu (1984) described changes in phytoplankton and zooplankton communities in a lake associated with mine tailing effluent. In general, a large body of literature related to mine effects and reclamation exists but is not referenced here.

Threats to wilderness water resources from events taking place outside wildernesses can be related to a number of activities, including water resource developments and operations, weather modification, air pollution, and dynamic natural biologic, hydrologic, and geologic processes.

We have seen a national and international increase in the amount of study directed at wet and dry atmospheric deposition. The public and scientific interest that has been produced in recent years as a result of ecosystem impacts in Europe, Canada, and the Northeastern United States is likely to continue for several more years. The scope of postulated effects from atmospheric deposition is broad. The impacts to water, both direct and indirect, have the potential of causing great change within wilderness water resources.

Much literature has been developed in Europe, Canada, and the United States covering the acid rain atmospheric deposition issue. Also, a number of good comprehensive reviews with bibliographies exist (USEPA 1985). A number of studies demonstrate that acid precipitation is occurring in wilderness areas (Lewis and Grant 1979, 1980; Huebert and others 1982). Recent findings also demonstrate the potential susceptibility of remote areas to atmospheric deposition (Herrmann and Baron 1980; Crisman and others 1980; Baron 1983; Gibson and others 1983; Welch and others 1984; Norton and others in press), and the ongoing U.S. Environmental Protection Agency lake survey will provide new knowledge about the chemical state of western wilderness waters. Studies have demonstrated increased heavy metal deposition in lake sediments (Galloway and Likens 1979) and that stream systems were maintaining cation stability by degrading soil buffer systems (Shaffer and Galloway 1982). A number of studies aimed at understanding catastrophic change in the natural chemical environment have looked to wilderness following the eruption of Mount St. Helens for representative natural study sites (Fahey 1979; Collins and others 1981; Dahm and others 1981; Lehre and others 1981; Staley and others 1982; Wissmar and others 1982; Welch and others 1984).

A wilderness lake in Canada was studied to determine the origin of its nonvolatile hydrocarbon content (Starnes and Brown 1976). The authors concluded that the hydrocarbons were of plant and animal, not human, origin. Other researchers have found natural sources of lake acidification (Patrick and others 1981; Helvey and others 1982). However, the available knowledge is limited.

The development and utilization of water resources, both existing and potential, offer the greatest possibility for direct impact to wilderness water resources values. The closing of Glen Canyon Dam has resulted in a long-term change in the hydrologic and geomorphic equilibrium of the Colorado River. Turner and Karpiscak (1980) identified changes in sediment load and discharge regime that have influenced the formation and destruction of riverbanks, bars, and terraces. They also cbserved dramatic changes in the amount of vegetation occupying sediment deposition sites with associated reductions in channel width.

A first-of-its-kind study has been initiated in the Holy Cross Wilderness in Colorado where construction is underway on a legislatively permitted transmountain water diversion within the wilderness boundary. The study (Cities of Aurora and Colorado Springs 1985) is intended to monitor streamflow, fish habitat, channel morphology, wetlands, and ground water to develop plans for mitigation of impacts, should any occur.

The potential for water development in the high mountain areas of many western wildernesses has long been recognized. Martinelli (1975) identified the potential to increase water yield through increasing snow deposition in alpine areas. Methods described include snow fences, terrain modification, intentional avalanching, and glacier building. Further, researchers have demonstrated that the melt rate of glaciers and snowfields can be modified through the application of various dusting agents (Slaughter 1966; Kotlyakov and Dolgushin 1972; Regelin and Wallmo 1975).

A major issue in wilderness management is weather modification. It has been estimated that the Upper Colorado River basin could experience an average increase in water yield of 0.9 to 1.3 million acre-feet per year through weather modification (Foehner 1977). In addition, it is felt that this could be done with little or no significant water quality degradation or stream channel effects (Foehner 1977). Questions remain, however, as to the long-term impacts on channels and lakes if a long-term net increase or decrease in precipitation were to occur. Knight and others (1979) demonstrated the potential for unmeasured effects that could arise as a consequence of increased water flow through soils and the need for further study.

One of the paramount values of wilderness is its role as a natural history record. As such, it serves as a barometer of environmental change. Whether of natural or human origin, change may be seen as the response of sensitive ecosystems to disturbances. Long-term study of water bodies found within wilderness is needed to: (1) identify and mitigate use-related impacts and (2) provide an early warning of future damages so that preventive or corrective actions can be applied to problem sources located outside wilderness.

To develop basic knowledge, data gathering studies have been implemented (Ghirelli and others 1977; Tunnicliff and Brickler 1984). Research into the geomorphology of channel features (Leopold 1975) exemplifies the approach to understanding natural hydrologic

systems. Studies aimed at protecting California alpine lakes and streams from user impacts (Flowers 1974; Kawaratani and Perrine 1975; Silverman and Erman 1979) examined baseline conditions for water chemistry, physical parameters, bacteria, plankton, and periphyton. Similar efforts in the East by Silsbee and Larson (1982) in the Great Smoky Mountains National Park included studying physical, chemical, and bacteriological water quality parameters for a year to determine the factors most important in controlling water quality and develop baseline information for long-term water quality monitoring and aquatic research.

In the Sierra Nevada Mountains of California, Melack and others (1982) intensively evaluated the buffer capacity of 23 alpine lakes; most were determined to be very weakly buffered. A high susceptibility to impact from acid deposition was therefore concluded. A similar finding was presented by Turk and Adams (1983) for lakes in the Flat Tops Wilderness of Colorado. After intensive study of 27 lakes, the authors concluded that approximately 370 lakes in the wilderness were sensitive to acidification.

Johnson (1981) measured unpolluted waters in southeastern Alaska to determine natural acidity. The data, he noted, can serve as a background for comparison with future measurements of water acidity. Similarly, Watling (1979) looked at wilderness lakes to establish background levels of trace and major metals. On a larger scale, Brown (1981) discussed the 33 designated biosphere reserves where samples of water and other components of the natural environment could be analyzed for organic and heavy metal contaminants delivered from the atmosphere.

The wide concern over the effects of atmospheric deposition on wilderness water resources values has also prompted a number of pollutant-monitoring baseline studies. Wiersma and others (1984) noted finding commonly reported background levels of trace elements, sulfate, and nitrate in remote areas of three National Parks: Great Smoky Mountains, Olympic, and Glacier.

Chemical data were collected for comparison of atmospheric, hydrologic, and biologic factors to baseline conditions. Substances entering the parks are perceived to have an unknown effect on the preserves' integrity, and decisions on acceptable levels of additional pollutants must be based on knowledge of ambient levels and the nature of effects. Careful field sampling techniques and high-resolution laboratory analyses were employed to assess levels, patterns, and trends of environmental contaminants. The use of multielemental analysis techniques has increased the speed of analysis and significantly reduced costs. These methods greatly increase the probability of detecting unnatural changes in chemical cycles and of understanding unusual chemical results. Comparative water chemistry data from Great Smoky Mountains, Glacier, and Olympic National Parks can be employed to establish relative levels of contamination (Wiersma and Brown 1979).

Installation of uniform wetfall/dryfall atmospheric deposition collectors in 28 parks, 11 of which are park/biosphere reserves, was accomplished as a part of cooperative efforts between the National Park Service, Man and the Biosphere Program of UNESCO, National Atmospheric Deposition Program (NADP), and the National Acid Precipitation Assessment Program (NAPAP) between 1980 and 1985. The network includes over 150 stations and presently provides a uniform controlled framework for sampling, data analysis, and quality control of physical and chemical data that is being applied nationally. Data from these stations provide the National Park Service and others with the ability to study what and how substances are impinging on natural resources and have resulted in the first tangible comparative data set for U.S. biosphere reserves (Herrmann 1982).

Understanding Past Research: The Present

Wilderness recreation has been said to be increasing faster than most forms of forest recreation and considerably faster than the national population growth rate (Jones 1975). The potential for impacts to wilderness water resources grows yearly, and can be expected to continue into the foreseeable future. The wilderness manager must therefore be provided with the means and the opportunity to identify and prevent adverse water resources impacts. Where impacts do occur, workable mitigative measures must be available.

The limited knowledge about wilderness is greatly augmented through analogy; pertinent nonwilderness studies can be utilized to some degree to help managers protect wilderness water resources. For example, Berry and others (1983) described six management strategies applied to commercial white-water rafting, specifically, river recreation management plans, land use controls, use limits, access permits, guide certification, and flow regulation. Recreationist information and education programs have been expanded as a consequence of research findings. As a result, recreationists have been alerted to potential health hazards and instructed in methods to reduce such hazards (Tunnicliff and Brickler 1984). Other applications of research findings include changes in backcountry waste disposal requirements, indirect methods for the estimation of water quality (Tunnicliff and Brickler 1984), recreationist registration, and group size limitations (Cieslinski 1977). The research on atmospheric deposition effects and processes has been of value in permit hearings for locating new air-polluting facilities.

Analysis of this current knowledge leads to a realization of the need for baseline data collection. All the impediments to wilderness research discussed (access, measurement difficulties, magnitude of consequence, and experimental design) are important considerations; however, as magnitude of consequences becomes more substantial, in real terms or in our perception, the likelihood increases that the obstacles will be overcome.

The direction wilderness or natural area water resources research is likely to take in the future is difficult to predict. The need for additional scientific inquiry into the effects of atmospheric deposition on wilderness

water resources seems to be evident, and results from the potential magnitude of both environmental effects and remedial cost, both on and off site. Reconnaissance surveys and baseline studies are evolving from the accelerated study of atmospheric deposition research.

The potential for water resources impacts due to water resources development or weather modification is at present unknown. Prediction of impacts resulting from development of water resources will require a better understanding of the mechanisms involved and their interrelationship with sensitive ecosystems.

The need for an effort in trend monitoring is beginning to surface in some areas. Such an activity will be of help in detecting environmental change resulting from increased recreational use and in defining carrying capacities.

The scarcity of research related to wilderness water resources will probably continue—until that time and in those places where the risks finally become so great that our lack of knowledge may result in the loss of the resource.

A STRATEGY FOR THE FUTURE

Reiteration of wilderness-related water resources research and monitoring activities is valuable. The important aspects of this knowledge increase our understanding of natural ecosystems and identify information needs for management of remote areas.

A number of approaches might be initiated to enhance our understanding of wilderness water resources or, more generally, wilderness resources. One preferred choice is a coordinated effort to establish a system of long-term ecological research sites at the watershed level. The remainder of the discussion revolves around concepts supporting this approach and the presentation of a sample long-term research program.

The watershed can be hypothesized within this larger ecological arena as an integrator of human and natural change. Alteration of fundamentally natural systems continues in the broader sense for the benefit of humans and their technology. Preserves as wilderness exist within this technological arena and are not isolated from the effects of this encroachment. Thus, the importance of wilderness research has been recognized. One cannot, however, detect change without having a baseline and cannot understand change without a knowledge of what is natural.

One can argue that a number of useful programs that are not uniquely wilderness form a broad definition of wilderness research that can lead toward an integrated approach. The proof of this argument depends on ongoing and future research that will enable the identification of the hypotheses. The program of remote area (wilderness) monitoring and research that is recommended has been applied in a limited number of cases (Wiersma 1979; Herrmann and Baron 1981; Baron 1983; Stottlemeyer 1984; Parsons and Graber 1985).

Analysis of combined hydrologic, biologic, and physical data sets has proved to be a good approach to develop a better understanding of remote natural (wilderness) resources. Interactive monitoring activities have included: (1) pollutant inputs and cycling data, including precipitation analysis; (2) climatic data; (3) permanent plot systems for monitoring changes in plant communities, soils, and soil waters, including chemical, physical, and biological change; (4) serial collection of chemical and biological data; and (5) population monitoring of select aquatic and terrestrial species. The benefits anticipated from continuing these activities in other remote or wilderness sites will include an increased ability to respond to new requirements, anticipate changing information requirements, understand the processes affecting resources, and evaluate new activities.

A preserve is dynamic, not static, and while we may not immediately notice slow, long-term, unexpected changes, it is important to know whether these changes are natural or human caused. We all must be concerned about today's issues, but through a coordinated set of watershed studies we can build a foundation for management of the entire ecosystem. In this manner we develop the mechanisms and the abilities to respond to the issues of tomorrow.

The experience of the National Park Service in implementing a long-term research program on the effects of acid precipitation on natural ecosystems and in developing pilot pollutant monitoring studies leads to the presentation of the following example as a point of departure for implementation of long-term wilderness watershed studies. These activities, when meshed with efforts of the National Science Foundation, Forest Service, and others can be the beginning of a national program for long-term ecological measurements and baseline studies in wilderness and equivalent remote natural areas.

Three sites were chosen to begin long-term watershed research related to atmospheric deposition during fiscal year 1983: Isle Royale, Rocky Mountain, and Sequoia National Parks. Olympic National Park was added in 1984. Each of these parks has been designated an International Biosphere Reserve, protects an example of a pristine or near-pristine ecosystem, and has a scientific research infrastructure and a history of use as a living scientific laboratory that enhances and benefits from the research proposed here.

Specific research was designed to meet the need for long-term data on the dynamics of undisturbed ecosystems and places emphasis on the study of ecological processes at the watershed level, using timeframes exceeding those commonly used in manipulative biological or ecosystems research. Each uses a standardized set of core measurements (table 1) while focusing on one or more specific areas of research. For Isle Royale the existing program of research was expanded to focus on the effects of acid deposition on boreal watershed/lake ecosystems. Within Rocky Mountain National Park the program emphasizes impacts on soil and water chemical processes. In Sequoia the research examines vegetation and aquatic community response across a broad elevation gradient. Finally, at Olympic there is an established background site approximating the lowest levels of known atmospheric pollutants in the continental United States.

Table 1.—Desirable measurements for long-term wilderness monitoring and research

Field to be measured	Data collected	Frequency	Methods
Precipitation (chemistry)	Deposition chemistry	Weekly	Bigelow 1982; NADP 1984
	Wet	Weekly	Bigelow 1982; NADP 1984
	Snow	Monthly	Herrmann and others 1982
	Dry		Protocol being developed
	Bulk collections	Weekly	Bigelow 1982; NADP 1984; Herrmann and others 1982
	Trace metals		EPA 1985
Climate	Windspeed and direction, humidity (or equivalent), temperature, incident solar radiation, precipitation amount	Continuous on site	Herrmann and others 1982
Vegetation	Permanent plots, phenology	Resurvey 5 years	Parsons and Graber 1984
Soils	Plots in a manner consistent with vegetation analysis	Remeasure 5 years	Herrmann and others 1982
Hydrology and aquatic studies	Temperature	Weekly (for 1 year)	Herrmann and others 1982
	Chemistry (major cations and anions)	Seasonal/event	EPA 1985
	Stream discharge	Continuous	Rantz 1982
	Lake stage (inflow-outflow measurements as needed for mass balance)	Continuous	Herrmann and others 1982
	Ground water mass balance (inputs/outputs)	One time—seasonal	
	Ground water (chemistry characterization)	Repeat 5 years	
	Characterize aquatic system and establish baseline of indicator species	5 years	Herrmann and others 1982
Paleolimnology	Sediment cores (diatom and heavy metals analysis)	One time	Baron and others 1985
	Pollen analysis, if possible	One time	Baron and others 1985

Interagency and interinstitutional cooperation on research and monitoring activities continues to involve state agencies, several universities, and federal agencies. The program structure incorporates what has been learned from the experiences of the National Science Foundation and reflects the thinking developed during formation of the National Science Foundation's Long-term Ecological Research Program (NSF 1977, 1979) and Man and the Biosphere monitoring protocols (USMAB 1979). Whole system studies resulting from this initiative are thought to be particularly useful for the partitioning and comparison of complex cause and effect relationships. In addition, the assessment, evaluation, and understanding of how pristine natural areas respond to human-driven change provide a predictive capability about potentially irreversible long-term changes.

A number of the objectives to be met directly support the goals of long-term ecological/watershed research: (1) detection of chemical changes within each ecosystem at the watershed level; (2) detection of biological change within each ecosystem at the watershed level; (3) establishment of nationally representative baseline sites; (4) partitioning of cause and effect relationships of long-term ecosystem change; (5) evaluation of how different unmanipulated natural sites will respond to acidification; (6) establishment of an early warning system for measuring ecosystem response.

The linkage by design of physical and ecological effects monitoring activities and baseline studies of natural systems at the watershed level pertains directly to our ability to test hypotheses.

Recommended Long-Term Measurement Activities

A program for continued long-term measurements provides: useful information on research questions, for improved management of wilderness and other preserved units, and for comparative studies among sites comprising the cooperative network. The approach described here presumes that ecological change is representable by a select number of physical and ecological variables. The core measurement strategy detects spatial and temporal differences of the measured variables. Site-specific long-term data sets employing standardized techniques of measurement are required for interecosystem comparisons or regional analogy. The core measurements program is designed to meet the following measurement criteria:

-Techniques will not be changed unless a new technique can be calibrated against the old.

-Sampling intervals should be within the timeframe of known biologic events.

-For descriptive studies or map measurements, scale and archiving will be compatible.

-Samples such as botanical materials, sediment cores, and known plankton or benthos will be cataloged and stored using standard museum procedures.

-Dynamic (physical or biological) measurements will employ techniques that can be accurately repeated.

-Techniques will allow partitioning of change into trends or cyclic events.

The study unit for long-term ecological measurements of effects is the watershed. A study site (wilderness, reserve) may consist of multiple watersheds, but within each watershed a number of physical and biological data sets or records are required to characterize the biota, climate, watershed, hydrology, geology, and the physical and chemical characteristics of soils, water, and the atmosphere. Together the data collections comprise a series of desirable baseline studies (Herrmann and others 1978; Franklin and Krugman 1979; Wiersma 1979; Wiersma and Brown 1979; Wiersma and others 1979; Hemstrom and Franklin 1981).

Repetitive measurements common to all sites include precipitation, climate, soils, vegetation, hydrology, aquatic samples, and paleolimnology (table 1). The proposed sets of measurements may not be appropriate to all areas or situations. They are meant as a beginning and a point of departure.

CONCLUSIONS

The focus of wilderness research should be an integrated program of long-term ecological research that has its foundation in the watershed. The hope is that the holistic design of this program will focus research activities toward a common objective that results in the development of data required for improved resource management and for solution of the complex research questions related to remote area or wilderness management. In the past, research, inventory, and monitoring were thought of separately. This program fuses the three into a directed program for the collection of data needed to test hypotheses relative to human contributions to long-term ecological change within wilderness environments.

This paper has covered the state of wilderness research as it relates to water resources. In the past the bulk of interest was health and safety and recreation, although for various reasons not a great deal of research was actually carried out in wilderness. A number of ongoing activities that have a holistic watershed approach to wilderness research were reviewed. Relying on the lessons learned from these activities, which have mainly been supported by the National Park Service, the National Science Foundation, and the U.S. Forest Service, a strategy for future wilderness/remote natural area research was presented.

For a program resulting from the application of these suggestions to be fully accepted, many of us must begin to think in terms of the knowledge required for long-term wilderness preservation. We again challenge present and future wilderness managers/land managers to utilize the foregoing concepts, concepts that will help to solve problems and achieve goals. The requirements facing us today are not new. The challenge is to perceive humans as a part of their environment and to meet our preservation commitments in a world of increasingly complex and changing objectives.

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Section 3. State-of-Knowledge for Wilderness User Research

WILDERNESS USE AND USER CHARACTERISTICS: A STATE-OF-KNOWLEDGE REVIEW

Joseph W. Roggenbuck
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ABSTRACT

Understanding wilderness use and users is essential for effective wilderness management, most of which is management of recreational use. Use and user research is less common now than a decade or two ago, although problems have multiplied and intensified as the wilderness system has expanded.

Similarities in use and especially users are more common than differences. Young adults, males, highly educated people, professional and technical occupations, moderately high incomes, predominantly local and regional visitors, low membership in conservation organizations, urban residents, considerable previous experience, and family groups are common characteristics. Use is distributed unevenly among areas, within areas, and over time. Parties typically are small, hiking, without outfitters, staying only a few days (or just for the day), and engage in multiple activities, with hiking, fishing, and photography most common.

The rate of increase in wilderness use has slowed, and use has declined in many areas. Use appears to be becoming more evenly distributed within many wildernesses with less pronounced peaks at certain times, stays are becoming shorter, parties are becoming smaller, there are more women visitors, and more visitors are visiting wildernesses not previously visited. The limited number of studies reporting data on these factors and noncomparability of measures and research methods require caution. Projections vary widely, although all project increasing use.

Research is needed to develop use measurement technology. Research needs to cover neglected areas and use outside the summer or summer and fall seasons, and be updated. Trends need emphasis, and longitudinal research is essential. A less cumbersome review and approval process is needed for research and monitoring. General population studies are needed as well as onsite visitor surveys. Visitors' knowledge of low impact use needs to be studied.

INTRODUCTION

Importance of the Topic

The importance of understanding wilderness use and user characteristics lies in the recognition that many of the important benefits of and threats to wilderness stem from wilderness use. The Wilderness Act (PL 88-577) specifies that the overriding value of wilderness is the protection of natural processes over a fairly large, undeveloped, and unoccupied area. However, the act recognizes that the protection of pristine areas is not an end itself. Instead, wilderness is "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness," and areas "shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness." The act goes on to specify in general terms what these user benefits are. Wilderness areas are to provide "outstanding opportunities for solitude or a primitive and unconfined type of recreation. . . and may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."

The Wilderness Act specifies in general terms the bounds of appropriate wilderness uses and benefits. However, more precise definitions are needed when wilderness allocation decisions are made, wilderness policy is developed, and management plans are written. Wilderness allocations are made in an arena of competing demands among potential uses of an area's resources. Undeveloped lands might be classified as wilderness, but they might also be used to meet the Nation's needs for energy, timber, or roaded recreation experiences. When such decisions are made, resource planners, the President, and the Congress need information on use patterns and how wilderness users define "solitude and primitive and unconfined recreation." They need to know what social, psychological, and economic benefits are gained, or lost, when lands are set aside as wilderness. They need to know who receives these benefits, where, and how. What are the trends in wilderness use? Is the number of beneficiaries growing or declining? Are some wilderness values increasing in importance while others are declining? The wilderness user can help answer these important questions.

Once wildernesses have been established, use and user information is a prerequisite to the preparation of sound management plans. Hendee and others (1978) have suggested a goal-achievement framework for wilderness management planning that calls for the statement of goals, objectives, current situation and assumptions, and management mechanisms. Knowing the current situation and trends in such variables as amount of use, methods of travel, timing of use, travel patterns, length of stay, and group size greatly facilitates the specification of feasible objectives and selection of management mechanisms to achieve them. User opinions are an important source of input to the development of objectives. Such user data as place of residence can help resource planners and managers locate important clientele groups and effectively plan public involvement and education programs.

Accurate information on use and users is important for the management of wilderness for two reasons. First,

wilderness management must for the most part be visitor management, because many other recreation management strategies are inappropriate. For example, site manipulation, site hardening, and facility development to prevent or mitigate impacts appear to conflict with the wilderness mandate for naturalness (Lucas 1982). Second, studies of wilderness users have consistently shown that freedom, spontaneity, and escape are highly sought values. Therefore, while visitor management is necessary, that management must be subtle, lighthanded, and unobtrusive (Lucas 1980, 1982; Wuerthner 1985). The wilderness manager must make every effort to permit users' freedom of choice—freedom at levels not necessarily found at less primitive outdoor recreation settings. This suggests that such authoritarian regulations as assigned departure times, entry points, travel routes, and campsites are generally inappropriate in wilderness. Instead, the manager might use access design and information, communication, and persuasion to modify behavior (Lucas 1981). Such management strategies require much more complete knowledge of use patterns, timing of use, and the attractions that draw visitors.

Information on use and users is also important in identifying causes and solutions of social and ecological impacts in wilderness. The relationship between amount of use and visitor-caused social and ecological impacts is not a linear one and depends on use characteristics as much or more than amount of use (LaPage 1967; Helgath 1975; Cole 1982). In explaining social impacts, and probably wildlife impacts as well, timing of use is often more important than amount of use; and visitor behavior, party size, and travel methods are more important than total use (Stankey 1973; Lee 1975).

Large increases in the number of wildernesses and the number of acres add to the importance of use and user research. From 55 areas, with 9 million acres, almost all in western States, all managed by one agency in 1964, the wilderness system has grown to 444 areas, with 89 million acres, in 44 States, managed by four agencies in 1984.

In summary, understanding use and user characteristics has value in itself, but it is also a key element in understanding many other dimensions of the wilderness social service system. By itself, knowledge of basic visitor characteristics permits an understanding of who, how many, when, where, and by what means people receive benefits from the wilderness. In addition, such visitor information can help wilderness policymakers, managers, and researchers understand the distribution of wilderness benefits among clientele groups, the behavior of users, and the causes and potential solutions to visitor-caused social and ecological impacts. When such visitor information is lacking for certain wildernesses or for large regions of the country, for certain seasons of the year, for certain user groups, or for key visitor characteristics, decisions must be based largely on intuition. Better knowledge of visitor characteristics increases the professionalism of wilderness management and can improve the quality of visitor experiences.

Scope of the Topic

Use and user characteristics relevant to wilderness allocation, planning, management, and research can be categorized roughly into five general areas: (1) basic demographic descriptions of visitors; (2) number and characteristics of visits; (3) motives for and benefits of use; (4) perceptions, attitudes, and behavior of visitors; and (5) trends and projections in use and user variables. In addition, knowledge of measurement methods is needed to obtain valid and reliable data on these use and user characteristics.

The scope of this paper is limited to research focusing on methods for collecting wilderness use and user data, basic demographic descriptions of wilderness visitors, characteristics of wilderness visits, trends and projections of use and users, and needs for additional use information. These basic user variables are closely related to motives for visiting wilderness, reasons for participating in various activities in wilderness, perceptions of conditions and experiences in wilderness, and wilderness attitudes and behavior. Motives, perceptions, attitudes, and behavior are often included in summaries of visitor surveys, but are omitted here. Stankey and Schreyer cover visitor attitudes and behaviors, and Driver, Haas, and Nash summarize wilderness benefits in separate papers in this volume. In addition, our summary is based almost entirely on published research reports, proceedings, journals, books, and selected theses and dissertations, with the addition of a few unpublished research reports. We have not reviewed the inhouse wilderness use and user records of resource management agencies except annual use reports. Finally, our literature review is largely limited to research completed on officially designated wilderness lands managed by the U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, National Park Service. Almost no published use and user research was found for U.S. Department of the Interior, Fish and Wildlife Service and Bureau of Land Management-managed lands, the other two Federal wilderness-managing agencies. Wilderness-related research conducted prior to 1964 when the Wilderness Act became law—most notably that in the Boundary Waters Canoe Area of Minnesota—was included, as was research on backcountry areas that later became or will likely soon become officially designated wilderness.

Our discussion of measurement methods describes the peculiarities of collecting visitor data in wilderness settings and identifies common problems that need to be addressed. Demographic characteristics of wilderness users included in our analysis are age, sex, education, occupation, income, place of residence, previous wilderness experience, group type, and club membership. Wilderness visit characteristics include amount of use, spatial distribution of use, time of use, party size, length of stay, method of travel, use of outfitter services, and visitor activities. Trend analyses and projections are reported for those few use and user variables for which sufficient longitudinal data are available.

GENERAL EVOLUTION OF RESEARCH

Focus

Use and User Characteristics Research.—Studies of wilderness use and user characteristics began in the late 1950's (Stone and Taves 1957; Taves and others 1960) and were emphasized in the 1960's (Bultena and Taves 1961; ORRRC 1962; Merriam 1963; Lucas 1964a; Merriam and others 1965; Burch 1966; Burch and Wenger 1967; Merriam and Ammons 1967; Hendee and others 1968). Active research continued to at least the mid-1970's (Jubenville 1971; Lime 1972; Murray 1974; Kennedy and Brown 1976; Stankey and others 1976; Bratton and others 1977; Nielsen and Shelby 1977; Echelberger and Moeller 1977).

In the early period, studies of use and user characteristics were a response to a perceived need to know who the users were, how many of them there were, and how they used wilderness. At the beginning of this period, there was a near vacuum of basic information about wilderness recreation, and great uncertainty about both its magnitude and characteristics.

Use Measurement Research.—A related topic, recreational use measurement technology, also received considerable research attention early (Lucas 1963; Wenger 1964; Wenger and Gregersen 1964; Lucas and Schweitzer 1965; Lucas and others 1971; James and Schreuder 1971, 1972; Elsner 1972; Lime and Lorence 1974; Lucas 1975; DeLand 1976; Marnell 1977; Ciali and others 1978; Gasvoda 1978; Plumley and others 1978) but less attention more recently (Kraushaar and others 1979; Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Scotter 1981; Saunders 1982; Lucas 1983; Huppuch and Pellerin 1984; Petersen 1985).

Several of the early use measurement studies, particularly those in which James participated, sought to develop overall systems for estimating use of an entire wilderness, usually based on integrating trail registers and traffic counters. James headed a Forest Service recreation research unit in North Carolina with a national mission of developing recreation use measurement methods for all types of recreation areas and wilderness. Many other studies, and almost all of the more recent ones, had much more limited objectives dealing with components of the use measurement process, such as trail register registration rates or use counting with electronic or photographic techniques.

Decline in Use/User Research.—In the 1960's there seemed to be a consensus that professional wilderness management required reasonably accurate recreational use measurement, that guesses and rough approximations were not adequate to plan for fieldwork and public contact, to assess trends, or for research on impacts and visitor perceptions of crowding. However, coordinated research to provide wilderness managers with this needed technology largely ended early in the 1970's when the Forest Service's recreation use measurement research unit in North Carolina was discontinued, probably just short of development of a satisfactory cost-effective system for wilderness, for reasons that are not clear to us.

Most of the early surveys of wilderness use and users were fairly comprehensive, covering visit characteristics such as activities, method of travel, and length of stay; group characteristics such as party size and type of social group; and individual socioeconomic characteristics including residence, age, sex, education, occupation, and income. Often attitudes and preferences were also studied and sometimes experience. The surveys were rarely "mere description" or simple censuses. They usually focused on management issues in the study area, and generally analyzed differences among various types of visitors, classified on a variety of bases, such as method of travel, personal wilderness orientation, and experience.

Comprehensive wilderness visitor surveys became scarce after the middle 1970's and nearly disappeared in the 1980's. Only a few use and user studies were published after 1977 (Leonard and others 1978; Plumley and others 1978; Roggenbuck and others 1979; Lucas 1980, 1985b), and these were based on data collected earlier. A survey of residents of southwest and south-central Alaska covered much wilderness-type recreation (Clark and others 1982). There also were basic visitor surveys of river recreationists (Lime and others 1981), including some rivers in wilderness settings.

This decline in research attention has many possible causes. Probably the major cause is a feeling, right or wrong, that the topic has been adequately dealt with, and that, in a sense, the answers are known. Furthermore, tighter budgets and research cutbacks have forced more concentration of research on the highest priority problems, and we sense that most researchers have considered use and user studies to be lower priority. Topics more closely related to visitor experiences and behavior and their explanation and management have been assigned higher priority. Researchers also have increasingly recognized the strengths of experimental approaches contrasted to survey research.

We do not disagree entirely with their positions, but we believe that all the answers to important questions are not known. First, trends in use and user characteristics are almost unstudied, and without further comparable studies our knowledge of trends will remain extremely skimpy. Second, wilderness use/user research has been very uneven in its coverage of the wilderness system and its use. As figure 1 shows, studies have been concentrated in the Northern Rockies, the Pacific Northwest, and northern Minnesota. Relatively few studies have been conducted in the East and California. The Desert Southwest and the South are little studied. River runners have been studied more widely (Lime and others 1981), including most of these regions, but wilderness users have not been studied nearly as evenly. (Differences in the difficulty of sampling the more widely dispersed wilderness visitors compared to river floaters probably contribute to this contrast. Rivers typically have fewer access points, while wildernesses commonly have a great many trailheads, over 70 in both the Boundary Waters Canoe Area and the Bob Marshall Wilderness complex, for example.) This has hampered analysis of patterns of variations among regions and agencies. Finally, we think many wilderness managers still feel a need for good profiles of their users.

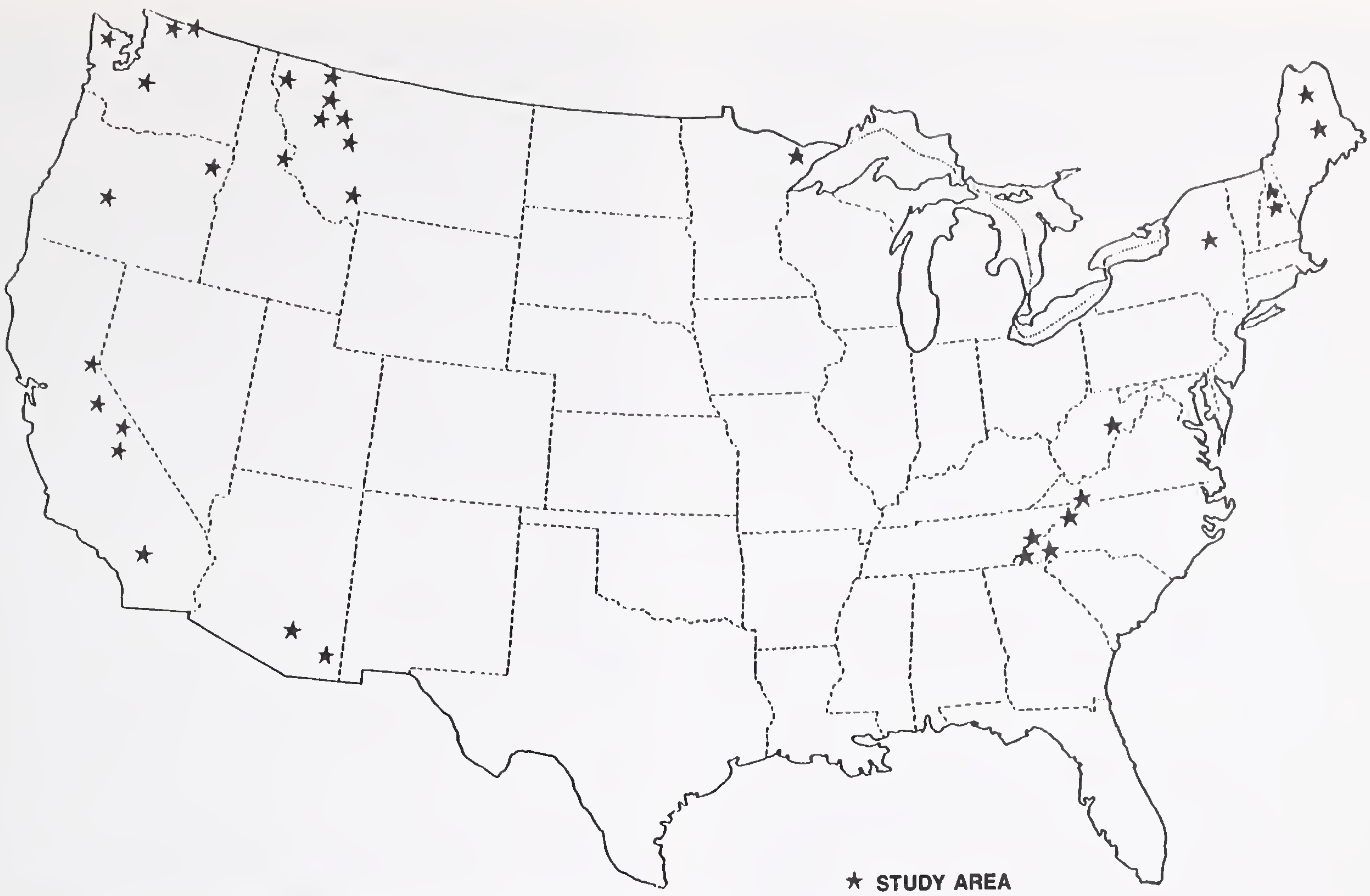

Figure 1.—Map of areas studied in published use and user research.

The shift in wilderness research emphasis in the 1970's away from basic descriptions of use and users and toward an understanding of the individual and social meanings and benefits of wilderness recreation resulted in part from an expanded and more comprehensive conceptualization of outdoor recreation. Prior to the 1970's, recreation was viewed primarily as participation in activities (Driver and Tocher 1970). Thus, fishing was recreation, swimming was recreation, and so on. There are many different types of fishing, for example, in highly varied settings that have little in common in terms of resources and management. Activity definitions of recreation may have hampered efforts to answer such important policy questions as "Why is the recreationist participating in the activity?" "What satisfactions or rewards are received from the activity?" and "How can the quality of the experience be enhanced?" (Driver and Tocher 1970, p. 10). To try to answer these questions, many recreation planners and researchers began to focus on the recreation experience: the sum of a participant's mental, spiritual, physiological, and other responses to a recreational engagement. Researchers expanded efforts to learn what outcomes wilderness users were seeking, their degree of satisfaction with the wilderness experience, perceptions of crowding within the wilderness setting, perceptions of conflict, and preferences for setting attributes that enhance wilderness experiences, stressing psychological research methods. In many of these studies, researchers also obtained information on socio-demographic characteristics of the wilderness visitors, but these data were generally collected only in an effort to better understand the dimensions of the wilderness experience or with the anticipation that such basic data could help planners and managers identify and meet the needs of varying clientele.

Another emphasis in wilderness user research focuses on visitor knowledge and actual behavior. This research thrust likely has several explanations. Wilderness managers have become increasingly concerned about user impacts on the land and others' experiences. At the same time, managers have become aware of the need to foster visitor freedom as a value of wilderness. Given this, managers have increasingly turned to education in an effort to lessen impacts (Washburne and Cole 1983).

Interest in behavior stems in part from the debate among social scientists in general (Deutscher 1973) and recreation researchers in particular (Heberlein 1973) on whether people behave as their knowledge, beliefs, or attitudes would suggest. When behavior is the issue of interest, as it often is in studies of conflict, crowding, and impact in wilderness, then behavior becomes the most relevant focus. Studies of both visitor knowledge and behavior have typically included some socio-demographic variables in an effort to explain study findings. Level of experience, for example, appears to influence users' tendency to respond to suggestions for use dispersal within an area (Lime and Lucas 1977; Roggenbuck and Berrier 1982).

Finally, in recent years there has been renewed research interest in visitor impacts on soil and vegetation in wilderness. This research has often included measures of amount, time, and type of use in an effort to better understand the relationships between use and impacts (Cole 1982, 1983; Marion and Merriam 1985).

Projections.—Research on wilderness recreational use projections has not been common (ORRRC 1962; Jungst and Countryman 1982; Hof and Kaiser 1983a, 1983b; Oliveira and others 1983). Unlike the basic surveys of use and users, all but one of the projection studies have been done recently. Projection research is hampered by the scarcity of recent visitor surveys to provide data on which to base projections.

Trend Research.—Trend analyses of use and users also have been scarce (Lucas 1967; Cieslinski 1980; Petersen 1981; van Wagtendonk 1981; Corti and others 1982; Lucas 1985a, 1985b; Burde and Curran 1986). As was true for use projections, all but one of the trend studies have been done in the last few years.

Development of Research Methods

Data Collection Problems.—Gathering data for studies of wilderness recreational use and users is difficult and costly if adequate samples are to be obtained. A number of characteristics of wilderness recreational use contribute to the difficulty.

Wilderness use is relatively light and widely dispersed. Typical wildernesses have many access points, and visitors spread out widely from the access points. Furthermore, use usually is highly variable from time to time, responding to weather, weekend leisure or weekday obligations, holidays, hunting and fishing seasons, and so on. As a result, the number of people present at any place at one time is usually low, and often there may be no one to contact or observe. Much fieldwork can produce little data, and costs are often high.

Another factor impeding efficient sampling is the lack of adequate basic use data to plan when and where to do fieldwork. Planning efficient access point sampling, for example, depends on reasonably good data on the distribution of use. The advantages of stratification or of sampling with probabilities proportional to size are reduced or lost if basic use data prove to be seriously inaccurate, as is sometimes the case.

Ethics sometimes limit certain kinds of data collection as well. Because of the particular character of the wilderness experience, disturbance of visitors during their experience may be undesirable. Many researchers have avoided contacting visitors within the wilderness, choosing rather to make contacts at access points before, or, more often, after the wilderness visit. Ethics also require care in use of observation techniques. Observation that might be fairly easy and unobjectionable in developed campgrounds where many people are normally present is a different matter for isolated campers in a wilderness who may believe they are the only people for miles.

Unobtrusive observation can take on some characteristics of spying, and can raise troubling questions of invasion of privacy and consent that researchers have had to face and deal with sensitively. This is an issue for both personal and photographic observation. More open, direct observation can also cause concern in some settings, particularly at campsites. Research has shown the high importance many wilderness visitors attach to campsite solitude (Stankey 1973). Researchers thinking of deliberately approaching visitors or camping near them for observational purposes have had to consider the importance of campsite solitude to some if not most of the visitors, as well as the effect their presence may have on the behavior being observed. These concerns add to the problems of efficiently gathering data on wilderness use and users.

Several studies have coped with these problems and used observation with care. Heberlein and Dunwiddie (1979) unobtrusively observed campsite selection and party characteristics at a popular lake in the Bridger Wilderness in Wyoming. Modified movie cameras provide another type of observation. Cameras either operate in a time-lapse fashion (Marnell 1977) or are triggered to expose one or a few frames by a trail traffic counter (Leatherberry and Lime 1981; Petersen 1985). Cameras have been used on trails and rivers, which are public places where visitors are passing by, not at campsites where privacy is more critical.

Analysis of agency wilderness use data is hampered by noncomparable units of measure used by the four Federal wilderness-managing agencies—National Park Service, Fish and Wildlife Service, Bureau of Land Management, and Forest Service. This has been a problem, for example, in trend analysis (Petersen 1981) and comparison of use intensity (Hendee and others 1978, chapter 13; Washburne and Cole 1983). Long-term trend analysis is also hampered by a shift in units of measure by the Forest Service in 1965 from visits and man-days to recreational visitor-days. No conversion factors exist.

Sampling Methods.—Early in the 1960-to-present period, survey research was almost the only approach used in wilderness use and user studies, and it has continued to be the most common technique. Survey methods have improved substantially over the years.

Sampling techniques have improved. Early in the 1960's, the existence of a length-of-stay bias in onsite visitor sampling was recognized (Lucas 1963) and ways of avoiding or correcting for it were developed (Lucas and Schweitzer 1965). Probability samples replaced informal convenience samples that had no definable relationship to the population of interest. For example, some very early surveys depended on interviews with whomever the researcher met while traveling through the wilderness. This resulted in small samples, length-of-stay bias (the probability of a visitor being contacted was a function of the length of time he was in the area), and geographically unrepresentative samples.

Most visitor survey field techniques produce cluster samples rather than simple random samples (Lucas and Oltman 1971). For example, fieldworkers typically are stationed at a particular access point for some limited time—such as part of a day. The resulting sample is a cluster of visitors for that time and place, and probably the sample is more homogeneous than an unclustered simple random sample of the same size. Early studies failed to recognize this property. Therefore, they were not designed to be as efficient as possible and improper statistical procedures were used. This weakness has been corrected in some studies, but misuse is still common.

Sources of visitor samples became more diverse, which often resulted in better samples. Personal contacts in the field were supplemented by use permits, special trail registers, outfitter guest lists, and so on. Approaches that

did not involve direct contact in the field usually depended on mail questionnaires. This technique was used more often in later studies, even those with initial personal contact, in contrast to more use of personal interviews in earlier studies. Mail questionnaire techniques were refined and achieved very high rates of return, usually in the 80 percent range, occasionally higher. Most mail questionnaires probably imposed less on visitors at access points than the more time-consuming personal interviews because of the desire by many visitors to either start their trip or head for home.

Visitors might have more time available for interviews inside the wilderness, especially at campsites. However, not only the ethical concerns raised before but also the sampling problems discussed make this an unsatisfactory approach to most research questions (although for studies of visitor perception of onsite conditions it is an appropriate method). In this situation, the mail questionnaire worked well and avoided problems with ethics and sampling design, and therefore it became a common approach. In contrast, telephone survey techniques (Field 1973) have rarely been applied to wilderness research.

Sampling Frames.—The unit of analyses in visitor use and user studies has been either the visitor group (often represented by the party leader), or individual members of the group, usually above some age such as 12 or 15. Party leader-based studies were probably more common in early research. Neither unit of analysis is necessarily superior; the appropriate unit depends on the study objectives. Most wilderness visitors are in groups; typically less than 10 percent of all parties consist of one person. Much group decision making and behavior results from intragroup social dynamics. But if describing the characteristics of wilderness visitors is an objective, studying only party leaders will produce seriously misleading results (Jubenville 1971).

Most wilderness use/user studies have been based on visitors to a particular wilderness. Very few have been household surveys that include nonvisitors—including former visitors and potential visitors. One exception is Young's (1983) survey of the general public in Illinois. Again, neither is right nor wrong except in relation to study objectives (Shechter 1977).

RESEARCH RESULTS

This section presents a comprehensive review of research on wilderness use patterns, user characteristics, use measurement strategies, trend analyses, and projections. Data typically are presented in tabular form broken down by area of study, year of study, and season of data collection. This permits analyses of differences in wilderness use and user characteristics by region of the country, season of the year, and across time. It permits the review of patterns among use and user variables, and also illustrates gaps in the data. Because the summary tables represent studies by many authors working at different times, under varying circumstances, with differing objectives, and using different data classifications, the precision of the information provided varies a great deal. For this reason, we have looked for and discussed replicated findings and gross patterns. Finally, we have often compared wilderness user characteristics to general characteristics of the United States population. This permits identification of the segments of the general population that are receiving the benefits of wilderness and those that are underrepresented.

Use Patterns

Amount of Use.—Of the four Federal agencies with lands included in the National Wilderness Preservation System, only the Forest Service separates wilderness from other dispersed recreation areas in its reports of recreational use. National Forest wilderness and primitive area use was 10.2 million standard 12-hour visitor-days in 1984. Use figures become more meaningful when reported on a per-acre basis. Visitor-days of recreation use of National Forest wilderness and primitive areas was 0.31 visitor-day per acre in 1984. Additions to the wilderness system, particularly large, lightly used areas in Alaska (which averaged only 0.05 recreation visitor-day per acre in 1984) have lowered the average concentration of use for the overall system.

The National Park Service records backcountry overnight stays, many of which occur in wilderness or similar undesignated parts of Parks. In 1984, overnight backcountry stays in 47 National Parks with designated or potential wilderness totaled 0.9 million. This is probably equivalent to about 1.8 million 12-hour recreation visitor-days. Day-use data are generally unavailable for National Park backcountry, in contrast to National Forest wilderness, but day-use is undoubtedly substantial for many of these four dozen parks. In Yosemite National Park, for example, visitor-days of day-use were estimated at roughly half or slightly less of the total visitor-days accounted for by overnight visitors (Hendee and others 1978). If this were the case for all parks, then the wilderness and backcountry parks accounted for about 2.7 million visitor-days of wilderness recreational uses in 1984. This would average less than 0.08 visitor-day per acre, with large, lightly used Alaskan areas pulling the average down. Wrangell-St. Elias National Park includes 8.7 million acres of wilderness and reported 1,931 overnight backcountry stays in 1984, about 0.0004 12-hour visitor-days per acre. Hendee and others (1978) estimated that use of all National Park backcountry and wilderness was 3 to 5 million visitor-days in 1975, although reported use has declined since then.

Time of Use.—Amount of use is distributed very unevenly across seasons of the year and days of the week in virtually all wilderness areas studied. Summer is the big season of use almost everywhere, generally accounting for 60 percent or more of all use (table 1). Even in areas such as the Bob Marshall and the Great Bear Wildernesses, famous for their fall big game hunting, summer use still substantially outnumbers fall use (Lucas 1980). Also, recent studies of three western wilderness areas suggest that the concentration of use during the summer season may be increasing (Lucas 1985b).

There are, however, brief peaks of off-season use in some wilderness areas. Popular hunting areas such as the Great Bear Wilderness have heavy use during the first week or two of the hunting season. Some areas in the South, Southeast, and low elevations in the Southwest and

Table 1.—Time of wilderness use, weekday or weekend and season, by area

Wilderness area (State)	Year	Season	Percent of total visitors: Time of week		Season of year[1]				Source
			Weekday	Weekend[2]	Summer	Fall	Winter	Spring	
Bob Marshall (MT)	1970	Summer/Fall	34	66	60	40			Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	27	73	82	18			Lucas 1980
Great Bear (MT)	1970	Summer/Fall	24	76	55	50			Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	43	57	86	14			Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	27	73	84	7			Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	42	58	71	28			Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	39	61	68	32			Lucas 1980
Desolation (CA)[3]	1972	All year	46	54	76	20	—— 4 ——		Lucas 1980
Great Gulf (NH)[4]	1976								
—day-use			66	34					Leonard and others 1978
—overnight use			68	32					Leonard and others 1978
Linville Gorge (NC)[4]	1978	Summer/Fall	47	[5]31(22)	66	34			Roggenbuck and others 1979
Shining Rock (NC)[4]	1978	Summer/Fall	40	[5]29(31)	56	44			Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)[4]	1978	Summer/Fall	44	[5]52 (4)	57	43			Roggenbuck and others 1979
Chiricahua Mountains (Cave Creek Canyon) (AZ)	1978-79	All year			32	19	11	39	Shaw and Richards 1979
Great Smoky Mountains NP backcountry (NC & TN)	1979	Winter	33	77					Hammitt and Hughes 1984
	1979	Summer	52	48					Hammitt and Hughes 1984
Bob Marshall Wilderness complex (MT)[6]	1982	Summer/Fall	42	58	77	24			Lucas 1985b

[1]Season of year percentages are percentages of total use of those seasons studied.
[2]Unless otherwise noted, weekend use equals wilderness use that began on Friday, Saturday, or Sunday.
[3]Figures for Desolation Wilderness represent percentages of total user groups.
[4]Weekend use is use that occurs on Saturday and Sunday.
[5]Figure in parentheses represents percentage of total visitors whose visits covered both weekends and weekdays.
[6]The Bob Marshall complex indicates the Bob Marshall, Great Bear, and Scapegoat Wildernesses.

southern California have spring peaks in use. For example, the Chiricahua Mountains of southeastern Arizona receive heaviest use in the spring. In the East and Southeast, fall color attracts many visitors during October. Finally, while winter use is generally light, it is much more common than a decade ago, and is growing.

In his studies of nine western wilderness areas, Lucas (1980) found that from two-thirds to three-fourths of all visitors entered the wilderness on Fridays, Saturdays, Sundays, and during the two summer holidays (Independence Day and Labor Day) (table 2). Hendee and others (1978) reported severe weekend peaking of use on such smaller, more accessible wildernesses as the San Gorgonio and San Jacinto in California, and they hypothesized that weekend peaking was probably common in eastern wildernesses. Recent research, however, suggests that concentrations of use on weekends are not as high as expected in the East. In the Great Gulf Wilderness, three National Forest wildernesses in the Southeast, and the Great Smoky Mountains National Park in the summer, weekday use accounted for 40 to 68 percent of all use. The eastern studies have been completed more recently, and they may reflect changes in use distribution across time. Lucas (1985b) noted that weekend peaking of use was less pronounced in the Bob Marshall Wilderness complex in 1982 than it was in 1970. In contrast, Hammitt and Hughes (1984) noted that 1979 winter backcountry use in the Great Smoky Mountains was highly concentrated on weekends. About 77 percent of all winter use there occurred on Saturday or Sunday.

Distribution of Use Among Areas.—The geographical distribution of wilderness use across areas is extremely variable (table 2). Some areas are heavily used, while others are virtually untouched. Heavily used areas tend to be located near population centers, often in the Southern Appalachians, New England, Minnesota, and California. Compared to the average visitor-day use per acre of National Forest wilderness in 1984 of 0.31, use of North Carolina wildernesses averaged 5.24; Indiana, 2.36; Tennessee, 2.29; Georgia, 2.07; Minnesota, 1.16; New Hampshire, 1.07; Alabama, 0.96; California, 0.73; and West Virginia, 0.79. At the same time National Forest wildernesses in the States of Alaska and Florida averaged 0.05, and Idaho, Montana, Nevada, and Wyoming averaged less than 0.25 visitor-day/acre.

Table 2.—Amount and intensity of recreational use of selected National Forest wildernesses, 1984[1]

Area	Total recreation visitor-days (RVD's)	RVD's per acre
Boundary Waters Canoe Area (MN)	1,252,700	1.16
John Muir (CA)	449,900	.77
Frank Church-River of No Return (ID)	368,800	.16
Absaroka-Beartooth (MT)	332,300	.36
Indian Peaks (CO)	332,000	4.72
Alpine Lakes (WA)	287,800	.78
Weminuche (CO)	263,300	.57
Selway-Bitterroot (ID-MT)	224,400	.17
Desolation (CA)	220,000	3.47
Bridger (WY)	218,100	.51
Emigrant (CA)	216,900	1.93
San Gorgonio (CA)	191,700	3.38
Rockpile Mountain (MO)	900	.22
Withington (NM)	900	.05
Bristol Cliffs (VT)	800	.21
Little Wambaw Swamp (SC)	800	.16
Wambaw Swamp (SC)	700	.14
Warren Island (AK)	500	.04
Muralla Island (AK)	500	.10
Endicott River (AK)	500	.01
Coronation Island (AK)	400	.02
Hell Hole Bay (SC)	100	.05
Shining Rock (NC)	123,700	6.70
Linville Gorge (NC)	72,900	6.64
Dome (NM)	29,800	5.73
Great Gulf (NH)	24,900	4.48
Never Summer (CO)	59,500	4.34
Gee Creek (TN)	9,100	3.65
Mt. Baldy (AZ)	25,700	3.63
Mokolumne (CA)	18,700	.18
Bob Marshall (MT)	148,300	.15
Bell Mountain (MO)	1,000	.11
Washakie (WY)	60,900	.09
Galiuro (AZ)	7,000	.09
Lee Metcalf (MT)	19,700	.08
Welcome Creek (MT)	1,900	.07
Kalmiopsis (OR)	12,000	.07
Hells Canyon (ID-OR)	13,100	.06
South San Juan (CO)	5,900	.05
Bradwell Bay (FL)	1,300	.05
Aldo Leopold (NM)	10,100	.05
Misty Fiords (AK)	39,300	.02
Total for all National Forest wilderness	10,209,300	0.31

[1]Based on the fiscal year from October 1, 1983, through September 30, 1984.

Eleven National Forest wildernesses reported over 200,000 visitor-days of use in 1984, and one, the Boundary Waters Canoe Area Wilderness (BWCAW), reported 1,252,700 visitor-days. These top 11 accounted for 41 percent of the total recreation use reported for the 165 areas designated at the beginning of 1984. Hell Hole Bay Wilderness in South Carolina had only 100 visitor-days of use, and nine other areas reported less than 1,000. Half of these lightly used areas were in the East, half in the West (most in Alaska). Low use in the eastern areas might be explained by their recent inclusion in the National Wilderness System or lack of scenic attractions.

The estimates of visitor-day use per acre suggest equally large variation in concentration of use across areas. Six National Forest wildernesses (Linville Gorge and Shining Rock in North Carolina, Indian Peaks and Never Summer in Colorado, Dome in New Mexico, and Great Gulf in New Hampshire) had visitor-day use in excess of 4.00 per acre. At the same time, five areas (South San Juan in Colorado, Aldo Leopold in New Mexico, Hell Hole Bay in South Carolina, the North Absaroka in Wyoming, and Bradwell Bay in Florida) had 0.05 visitor-day per acre or less, as did nine National Forest wildernesses in Alaska.

Limited National Park Service data also indicate uneven distribution of use across areas. Yosemite, Sequoia, Kings Canyon, and Grand Canyon National Parks all reported close to or over 100,000 backcountry overnight stays in 1984. During the same year, several National Parks with wilderness-type lands, including Badlands, Big Thicket, Cape Krusenstern, Craters of the Moon, Death Valley, Kobuk Valley, Katmai, and Lava Beds, reported less than 1,000 overnight stays. Some reported no use.

Intra-Wilderness Use Distribution.—Use varies as much within as between wilderness areas. In studies of entry point use, one entry point sometimes accounts for over half of all use. Lucas (1964a) found that 52 percent of all paddling canoeists in the BWCA originated from one access point. In 1974, seven of the BWCA's 70 entry points accounted for 70 percent of all use (table 3). In 1984, use was reported for 88 entries; the top 10 accounted for 51 percent of all use. In Lucas' study of nine western areas (Lucas 1980), just three trailheads accounted for half or more of all use in every area except the Selway-Bitterroot. Generally, one-fourth of the access points had 80 percent or more of all use. In each of the nine areas, some of the trailheads were not used by any of the sampled individuals. Disproportionately high use of only a few entry points seems less pronounced in the East, but use is even more concentrated at trailheads in Yosemite National Park (table 3).

Lucas (1985b) has reported some dispersal of use to more lightly used trailheads recently in the Bob Marshall, Great Bear, and Scapegoat Wildernesses. In 1970, between 7 and 25 percent of the entry points to each of these three areas accounted for 80 percent of all use. In 1982, this amount of use entered at 33 to 45 percent of the areas' trailheads.

Use of trail segments inside wildernesses is also extremely variable. For example, while the Spanish Peaks Primitive Area had one of the most even trail use distributions among areas that Lucas (1980) studied, about 50 percent of all its visitor-miles of travel occurred on 10 percent of its trail miles. Thirty percent of its trail miles had 70 percent of all visitor use. Similarly, on some lakes in the Boundary Waters Canoe Area, contacts with other parties of canoeists are more than 40 times as numerous as on other lakes (Lime 1975). Variations in trail use concentration appear to be little related to either area size or intensity of use, but instead seem to be related to trailhead location relative to population centers, ease of road access to trailheads, location of attractions within the area, extent of trail development and trail configuration

Table 3.—Concentration of total wilderness use among high use entry points by area

Wilderness area (State)	Year	Season	High use entry points: Percent of total entry points	Percent of total use	Source
Bob Marshall (MT)	1970	Summer/Fall	25	83	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	50	81	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	9	85	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	25	81	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	38	82	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	25	85	Lucas 1980
Selway-Bitterroot (MT & ID)	1970	Summer/Fall	26	82	Lucas 1980
Desolation (CA)	1970	Summer/Fall	29	83	Lucas 1980
Boundary Waters Canoe Area (MN)	1974		10	[1]70	Hendee and others 1978
Indian Peaks (CO)	1976	Summer	44	78	Brown and others 1977
Yosemite NP back-	1973	All year	4	68	van Wagtendonk 1981
country (CA)	1979	All year	4	60	van Wagtendonk 1981
Maroon Bells-Snowmass (CO)	1978	Summer	23	80	Haas and others 1982
Linville Gorge (NC)	1978	Summer/Fall	21	55	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	38	85	Roggenbuck and others 1979
Great Smoky Mountains NP	1979	Winter	29	[1]88	Hughes 1985
backcountry (NC & TN)	1979	Summer	26	[1]77	Hughes 1985
Bob Marshall (MT)	1982	Summer/Fall	37	79	Lucas 1985b
Great Bear (MT)	1982	Summer/Fall	33	81	Lucas 1985b
Scapegoat (MT)	1982	Summer/Fall	45	80	Lucas 1985b

[1]Percent of total user groups.

within the area, and distance from trailhead to the wilderness periphery.

Distribution and amount of use of campsites within wildernesses also vary a great deal, with much use concentrated at popular attractions. Large, reasonably accessible lakes are an important attraction for campers almost everywhere. In an inventory of campsites in the Spanish Peaks Primitive Area, Brown and Schomaker (1974) found that half of all campsites were within 50 feet of a lake or stream, two-thirds were within 100 feet, and 85 percent were within 200 feet. Depending on such variables as accessibility, proximity to water, and presence of a view, use of individual campsites is uneven. For example, 16 percent of the campsites in the Desolation Wilderness accounted for over half of all use; the least-used half had only 18 percent of all use (Hendee and others 1978). Many campsites in the 1982 study of the Bob Marshall Wilderness complex were estimated to receive less than 30 nights of use during the use season, but a number had over 120 nights of use (or almost constant use). Finally, Hughes (1985) reported more concentrated campsite and shelter use in the Great Smoky Mountains National Park backcountry in winter than in summer. Approximately 62 percent of winter campers used shelters, compared to 40 percent in summer. In winter, two of the park's 18 shelters accounted for 33 percent of all shelter use, and eight shelters had 73 percent of all use. In contrast, two shelters had 18 percent of all shelter use in summer, and seven had 53 percent.

Party Size.—Most wilderness parties (groups of individuals traveling together) are small, and appear to be getting smaller. For all areas studied, at least half of all groups were two- to four-person groups (table 4). In some areas groups of this size accounted for 75 percent of all parties. Two-person groups are the most common. Lone individuals are scarce in wilderness, as are groups with over 10 people. For most National Forest areas studied, the percentage of one-person groups was only about 5 to 10 percent. Interestingly, lone individuals using National Park backcountry were more numerous, generally equaling between 10 and 15 percent of all user groups. Parties of more than 10 people usually numbered about 5 percent of all groups everywhere. Two notable exceptions were Montana's Scapegoat Wilderness in 1970, with 14 percent, and California's San Gorgonio Wilderness in 1972, with 25 percent. Average size of user groups was somewhat smaller in National Park wilderness and backcountry than in National Forest wilderness. While parties averaged four to five people on National Forests, averages were typically two to three individuals on National Park lands.

Large parties were more likely to be horse users or river rafters than hikers, and campers rather than day-users, in Lucas' (1985b) study of the Bob Marshall Wilderness complex. Hunters and nonhunters had similar proportions of large parties. Finally, Lucas (1985a) suggested that group size may be getting smaller. In 1970, groups in the Great Bear and Scapegoat Wildernesses averaged 5.2 and 5.6 individuals, respectively. By 1982, these numbers had declined to 3.8 and 4.4. Many areas have placed restrictions on group size in an effort to reduce ecological and social impacts in wilderness. These limits, however, have typically been larger than most groups, so this regulation has likely had little effect on average group sizes. Users themselves, particularly the leaders of organized groups, have apparently become aware of the disproportionately high impacts of large groups, and have reduced their group sizes.

Table 4.—Party size of wilderness visits by area

Wilderness area (State)	Year	Season	Average size	Percent of total parties of indicated size[1]: 1	2-4	5-10	11+	Source
Boundary Waters Canoe Area (MN)[2]	1961	Summer	5.0					Lucas 1964a
Bob Marshall (MT)	1970	Summer/Fall	4.7	6	50	42	2	Lucas 1980
	1982	Summer/Fall	4.7	6	61	25	8	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	4.0	5	69	17	4	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	5.2	0	66	27	7	Lucas 1980
	1982	Summer/Fall	3.8	5	72	22	1	Lucas 1985b
Scapegoat (MT)	1970	Summer/Fall	5.6	6	60	20	14	Lucas 1980
	1982	Summer/Fall	4.4	11	60	23	6	Lucas 1985b
Mission Mountains (MT)	1970	Summer/Fall	4.5	5	56	31	5	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	4.8	8	56	27	6	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	4.5	5	65	22	6	Lucas 1980
Desolation (CA)	1972	All year	3.8	10	66	18	4	Lucas 1980
John Muir (CA)	1972			9	72	12	7	Hendee and others 1978
San Gorgonio (CA)	1972			7	53	15	25	Hendee and others 1978
Yosemite NP back-country (CA)	1972			14	71	12	3	Hendee and others 1978
Sequoia-Kings Canyon NP (CA)	1972			13	75	7	5	Hendee and others 1978
North Cascades NP (WA)	1974			13	63	18	6	Hendee and others 1978
Olympic NP (WA)	1974			14	72	9	5	Hendee and others 1978
Mount Rainier (WA)	1974			13	71	14	2	Hendee and others 1978
Yosemite NP back-country (CA)	1972	All year	3.2					van Wagtendonk 1981
	1973	All year	3.1					van Wagtendonk 1981
	1974	All year	3.0					van Wagtendonk 1981
	1975	All year	3.0					van Wagtendonk 1981
	1976	All year	2.8					van Wagtendonk 1981
	1977	All year	3.0					van Wagtendonk 1981
	1978	All year	3.0					van Wagtendonk 1981
	1979	All year	2.7					van Wagtendonk 1981
Great Smoky Mountains NP backcountry (NC & TN)	1976	All year	2.8	16	73	—10—		Bratton and others 1977
Great Gulf (NH)	1976	Summer	3.0	— [3]50 —				Leonard and others 1978
Indian Peaks back-country (CO)	1976	Summer	2.9	11	73	— 16 —		Brown and others 1977
Weminuche (CO)	1977	Summer	4.4	9	64	21	7	Haas 1979
Eagles Nest (CO)	1977	Summer	3.6	7	74	16	5	Haas 1979
Rawah (CO)	1977	Summer	4.0	6	72	18	6	Haas 1979
White Mountains (NH)	1977-78	Winter	3.9	7	64	21	7	Taylor and Mackoy 1980
Linville Gorge (NC)	1978	Summer/Fall	4.9	— 73 —		19	8	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	4.4	— 76 —		17	7	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall	3.1	— 85 —		11	3	Roggenbuck and others 1979
Popo Agie (WY)	1978	Summer	3.1	16	69	14	1	Manfredo 1978b
Bridger (WY)	1978	Summer	3.2	16	62	21	1	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	3.6	20	58	19	3	Manfredo 1978b
Maroon Bells-Snowmass (CO)	1978	Summer	3.3					Haas and others 1982
Great Smoky Mountains NP backcountry (NC & TN)	1979	Summer	2.7	15	74	11	0	Hughes 1985
	1979	Winter	2.6	14	77	9	0	Hughes 1985
	1983	Summer	3.3	16	66	19	0	Burde and Curran 1986
Pusch Ridge (AZ)	1979-80	All year		— [3]74 —				Purdy and Shaw 1981

[1]Percentages may not always add to 100 because of missing data.
[2]Data represent paddling canoeists.
[3]Figures represent percentage of one- and two-person parties.

Method of Travel.—Hiking is the most common travel method in all wilderness areas studied except the Bob Marshall in Montana and the Boundary Waters Canoe Area in Minnesota (table 5). Typically, from 60 to 90 percent of all users of Rocky Mountain wildernesses are hikers. Most of the remaining users travel on horseback, and a few hike with packstock. In the East and in California's Desolation Wilderness, virtually all use is by hikers. Horse use in the East is extremely low where it has been reported, and most studies do not even have a horse-use category.

Exceptions to the predominance of hikers in areas are large, horse-oriented areas like the Bob Marshall, the Great Bear, and perhaps the Teton Wilderness and Idaho Primitive Area (now the Frank Church-River of No Return Wilderness) (Hendee and others 1978). But even in at least some of these areas, hiking use has grown much faster than horse use. For example, the ORRRC study (1962) estimated that 90 percent of all Bob Marshall visitors were horse users in 1959. By 1970 this number was 59 percent (Lucas 1980), and in 1982 there was an even split between the horse users and hikers (Lucas 1985b). The shift away from horse use and toward hiking use was the biggest change that Lucas (1985b) found in his comparison of 1970 and 1982 use and users of the Bob Marshall, Great Bear, and Scapegoat Wildernesses. In 1970, horse users were the clear majority in this three-area complex. By 1982, the situation had reversed, and hikers had become the most common users.

In the Lucas study (1985b) of the Bob Marshall Wilderness complex, hunters were predominantly horse users (79 percent used horses in 1970 and 69 percent in 1982). In contrast, the percentages of nonhunters using horses were 42 and 32 in 1970 and 1982, respectively. Campers were more likely than day-users to be horse users, but here, too, horse use was declining. In 1970, 61 percent of campers and 31 percent of day-users were on horseback. By 1982, these percentages had dropped to 45 percent and 15 percent. Finally, numbers of horses per horse-using party have declined from 12 in 1970 to about nine in 1982.

The Boundary Waters Canoe Area is a unique water wilderness, and there most people travel by boat or canoe. In 1984, 75 percent of all visits May through September were by paddling canoeists, 21 percent were by motor-powered canoes or motorboats, and 4 percent were by hikers.

Outfitter Use.—The number of wilderness visitors who use outfitter services ranges from none in many eastern and small western areas to a majority on such famed whitewater wilderness rivers as the Colorado, Middle Fork of the Salmon, and the Selway. Outfitters are common in many large, horse-oriented western wildernesses, but even in the most popular areas, visitors who employ outfitters are a distinct minority. About 35 percent of all Bob Marshall and Great Bear visitors in 1970 used outfitters (table 6). For all other areas studied, percentage of visitors employing outfitters was less than 8, and in most areas the percentage was less than 1. In the Bob Marshall, close to half the people using horses did not use outfitters (Lucas 1985b). In contrast, only 15 to 20 percent of the horse users in the Great Bear traveled without outfitters.

Outfitting is often associated with hunting and is therefore much more common in the fall. For example, Lucas (1985b) found that 41 percent of the hunters in the Bob Marshall Wilderness complex (an area comprised of the Bob Marshall, Great Bear, and Scapegoat Wildernesses) employed outfitters in 1970; only 20 percent of the nonhunters did. About 29 percent of the Bob Marshall visitors in the summer season used outfitters; this percentage increased to 47 in the fall. Similarly, just 4 percent of the summer Selway-Bitterroot users employed outfitters, but this figure reached 23 percent in the fall.

While outfitting is a sizable industry on many rivers and in large western wildernesses, the percentage of wilderness users employing outfitters appears to be declining. As one example, Lucas (1985b) found that 31 percent of the visitors to the Bob Marshall Wilderness complex used outfitters in 1970, but this percentage decreased to 17 in his 1982 study. A drop occurred in both the summer and fall seasons (table 6).

Length of Stay.—Wilderness visits are typically short. For many small- to medium-sized wildernesses, 1-day visits predominate (Hendee and others 1978). Even in several large western wilderness areas, day visits are the majority. For example, Lucas (1980) found that more than 60 percent of all visits to the Cabinet Mountains and Mission Mountains Wildernesses and the Spanish Peaks Primitive Area of Montana were 1-day visits. Even in the very large Selway-Bitterroot Wilderness in Idaho and Montana, 48 percent of all visits were for a day or less (table 5). At the same time, long trips (trips of a week or more) were rare, accounting for less than 10 percent of visits to all areas except the Bob Marshall and the Great Bear. Half of the western areas studied had no sampled trips longer than 1 week. Average length of stay was typically 2 to 3 days across areas in all regions of the country. Exceptions were the Boundary Waters Canoe Area, Bob Marshall, Great Bear, and Great Smoky Mountains summer users, where lengths of stay averaged from 4 to 5 days. Users of the Popo Agie, Bridger, and Fitzpatrick Wildernesses in Wyoming also had longer stays, perhaps partly due to very long trips by classes from the National Outdoor Leadership School located nearby.

Lucas (1980, 1985b) reported that certain kinds of users have more lengthy stays. Among nine areas that he studied in 1970, horse users averaged a 3.8-day length of stay; this average was 2.2 for hikers. The difference was even greater for the Bob Marshall Wilderness complex, where horse users in 1970 stayed an average of 7.4 days, but hikers stayed for only 2.9 days. Much of the difference between horse users' and hikers' length of stay appears due to differential proportions of day-users. About 32 percent of all hikers were day-users; only 8 percent of the horse travelers stayed such a short time. Hunters and nonhunters had similar lengths of stay in 1970, but by 1982, hunters in the Bob Marshall complex were staying longer than nonhunters (6.7 compared to 4.3 days).

While Hendee and others (1978) suggested that increased travel costs would likely cause wilderness use to shift to fewer but longer trips, recent research suggests that wilderness trips are getting shorter. Lucas (1985b) found visits to the Bob Marshall Wilderness complex to average 5.7 days in 1970; by 1982, trip length had decreased to 4.7 days. Length of stay for horse users dropped from 7.4 days in 1970 to 6.7 days in 1982. The gradual decline in average length of stay in wilderness

Table 5.—Method of travel and length of stay for wilderness visitors by area

Wilderness area (State)	Year	Season	Percent of total visits by travel method: Hike	Horse	Hike with stock	Other	Avg. stay	Percent of total visits of each length (days): 1	2-3	4+	Source
Boundary Waters Canoe Area (MN)	1961	Summer					5.1				Lucas 1964a
Bob Marshall (MT)	1964	Summer/Fall					8				Merriam and Ammons 1967
Mission Mountains (MT)	1964	Summer/Fall					2				Merriam and Ammons 1967
Glacier NP backcountry (MT)	1964	Summer/Fall					4				Merriam and Ammons 1967
Eagle Cap (OR)	1965	Summer					3.0				Hendee and others 1968
Three Sisters (OR)	1965	Summer	85	15	0	0	2.2				Hendee and others 1968
Glacier Peak (WA)	1965	Summer	82	18	0	0	2.2				Hendee and others 1968
Bob Marshall (MT)	1970	Summer/Fall	31	59	6	4	5.7	14	23	56	Lucas 1980
Bob Marshall Wilderness complex (MT)	1982	Summer/Fall	57	36	6	4	4.7	22	24	54	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	90	7	2	1	1.6	67	25	7	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	46	42	0	15	4.9	25	13	63	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	97	2	1	0	1.7	62	28	10	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	72	20	7	1	1.9	63	22	12	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	70	20	6	5	2.9	48	25	29	Lucas 1980
Desolation (CA)	1972	All year	99	0	1	0	3.3	17	42	40	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	64	18	12	1	2.9	41	37	22	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71										
—low experience		Summer/Fall						78	13	9	Murray 1974
—moderate experience								46	37	17	Murray 1974
—high experience								35	23	42	Murray 1974
Yosemite NP backcountry (CA)	1972	All year					2.9				van Wagtendonk 1981
	1973	All year					3.0				van Wagtendonk 1981
	1974	All year					2.7				van Wagtendonk 1981
	1975	All year					2.8				van Wagtendonk 1981
	1976	All year					2.6				van Wagtendonk 1981
	1977	All year					2.6				van Wagtendonk 1981
	1978	All year					2.4				van Wagtendonk 1981
	1979	All year					2.8				van Wagtendonk 1981
Boundary Waters Canoe Area (MN)	1974	All year	3	N/A	N/A	[1]97					Hendee and others 1978
	1984	May-Sept.	4	N/A	N/A	[2]96					Superior NF 1984
Great Smoky Mountains NP backcountry (NC & TN)	1976	All year					2.5		64	36	Bratton and others 1977
Weminuche (CO)	1977	Summer					3.4	16	25	59	Brown and Haas 1978
Eagles Nest (CO)	1977	Summer					1.4	36	48	16	Brown and Haas 1978
Rawah (CO)	1977	Summer					2.3	12	53	34	Brown and Haas 1978
White Mountains (NH)	1977-78	Winter						60	— 41 —		Taylor and Mackoy 1980
Linville Gorge (NC)	1978	Summer/Fall					2.7	37	52	12	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall					2.8	29	54	18	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall					2.9	24	52	24	Roggenbuck and others 1979
Yosemite NP backcountry (CA)	1978	Winter						80			Gilbert 1980
Popo Agie (WY)	1978	Summer						7	38	55	Manfredo 1978b
Bridger (WY)	1978	Summer						11	31	59	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer						12	16	72	Manfredo 1978b
Maroon Bells-Snowmass (CO)	1978	Summer						38	43	19	Haas and others 1982
Baxter State Park (ME)	1979	Summer					2.7	37	41	22	Reiling and others 1981
Great Smoky Mountains NP backcountry (NC & TN)	1979	Summer	97	3	0	0	3.0		50	50	Hughes 1985
		Winter	100	0	0	0	2.1		74	26	Hughes 1985
Pusch Ridge (AZ)	1979	All year									
	1980	All year						78			Purdy and Shaw 1981
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer					4.5	18	33	50	Burde and Curran 1986

[1]57 percent paddle canoe, 10 percent motor canoe, 28 percent motorboat, 3 percent snowmobile (Lime and Buchman 1975).
[2]75 percent paddle canoe, 21 percent motor canoe or boat.

Table 6.—Percent of total wilderness visits that employ outfitters

Wilderness area (State)	Year	Season	Visits that use outfitters Total	Summer	Fall	Source
Bob Marshall (MT)	1970	Summer/Fall	35	29	47	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	35			Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	<1			Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	<1			Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	<8			Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	<8			Lucas 1980
Bob Marshall Wilderness	1970	Summer/Fall	31	21	46	Lucas 1985b
complex (MT)	1982	Summer/Fall	17	14	24	Lucas 1985b
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	<8	4	23	Lucas 1980
Desolation (CA)	1972	All year	<1			Lucas 1980

seems due to the presence of proportionately more hikers, fewer horse users, and fewer hunters.

Wilderness Activities.—Recreationists typically participate in a variety of activities during a wilderness trip. For example, Lucas (1980) found that users of nine western wilderness areas averaged 2.5 to 3.1 activities during their visits. Hiking, fishing (where it is possible), and photography were the most common activities (table 7). At least three-fourths of all visitors to virtually all areas hiked. More than half of all visitors fished or took pictures. Hendee and others (1977), however, reported that fishing was often incidental to other activities in wilderness, and was only engaged in for limited times during the trip. Nature study (such as birdwatching, wildlife observation, plant identification, amateur geology) is generally the most common activity after photography. Swimming is common in many places, particularly in areas in the Southeast and California (table 7). Mountain climbing is rare except for a few areas. Hunting in National Forest wildernesses ranges from almost none to fairly common, but is generally less common than might be expected. Of all areas studied, only in the Bob Marshall and the Great Bear did more than 20 percent of the sampled visitors hunt. Even in the fall hunting season, many visitors were not hunters. For example, Lucas (1980) reported that 30 percent of the Selway-Bitterroot users and 80 percent of the Mission Mountains visitors were not hunting during this period.

Activity participation also varies by season of year and type of user (Lucas 1980). Almost all hunting, of course, occurs in the fall; most other activities predominate in the summer. Summer visitors engage in more activities per trip than fall users. Hikers are much more likely to study nature or swim than horse users, but horse travelers tend to hunt and take pictures. Fishing is common among both user groups. Campers engage in a greater variety of activities per visit than day-users, but nature study and hunting are common among single-day visitors.

Lucas (1985b) recently studied activity participation for the Bob Marshall, Great Bear, and Scapegoat Wildernesses and found little change in number and kind of visitor activities between 1970 and 1982. Hiking, fishing, and photography remained important. Of these, only fishing declined, and only slightly. Hunting was the only activity with a substantial change, and it dropped in importance (table 7). These data suggest that there may be a slight shift away from the more consumptive uses of wilderness toward more contemplative activities.

Variation in Use Patterns

While use patterns show considerable similarities across areas, differences do exist. These variations appear to be explained in large measure by some combination of the following 12 variables: region, proximity to population centers, area size, character of the resource, presence of attractions, managing agency, time of establishment as wilderness, extent of area access, time (season and year), trail system configuration, type of user, and tradition.

Region.—Several authors have examined differences in wilderness use patterns by region of the country, and fewer differences have been found than were initially expected (Roggenbuck 1980; Timm 1980; Boteler 1981). Regions of the country with high population concentrations tend to have wildernesses with high use. New England, the Southeast, the Midwest, and California are examples. But each of these regions has some wildernesses with very low use. Time of wilderness use is also significantly influenced by regional location. Early spring or fall color use reduces the typical peaking of summer use in some areas in southern Arizona, southern California, and the Southeast. Weekend peaking appears less severe in the East, at least in summer. Apparently more visitors there use wilderness while on their annual vacation. Horse use and therefore outfitting use are almost nonexistent in eastern wilderness.

Proximity to Population Centers.—Proximity to population centers seems to be an even better predictor of total amount of use than regional location. Also, relationship of the wilderness to nearby urban centers strongly influences distribution of visitor use among the area's trailheads and trail segments. Those entry points and trails closest to population concentrations receive the most use. Weekend peaking of use is much more severe among areas located near population centers, at least in the West.

Area Size.—Size of wilderness has considerable influence on type and distribution of use among trail segments. Extremely large areas are much more likely to have a higher proportion of horse use. Outfitting tends to be more common in large areas. Trail segments deep inside vast areas typically have less use than those in the heart of smaller areas.

Character of the Resource.—The character of the wilderness resource—its ecosystem characteristics—

Table 7.—Wilderness activities participated in by area

Wilderness area (State)	Year	Season	Percent of total visits involving the activity: Fish	Hunt	Hike	Photography	Nature study	Mountain climbing	Swim	Cross-country skiing	Snow shoeing	Other[1]	Source
Bob Marshall (MT)	1970	Summer/Fall	61	34	58	58	28	0	11			18	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	61	6	81	45	25	2	15			19	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	62	43	54	53	15	0	4			16	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	74	2	79	56	31	2	18			8	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	41	16	70	53	29	4	9			7	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	62	11	74	53	27	2	20			14	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	43	16	75	58	35	2	17			7	Lucas 1980
Desolation (CA)	1972	All year	48	1	94	54	52	4	46			11	Lucas 1980
Adirondack High Peaks (NY)[2]	1974-75	Winter			25			32		36	19		Snowden 1976
Weminuche (CO)	1977	Summer	52		92	73	42	8					Brown and Haas 1978
Eagles Nest (CO)	1977	Summer	46		94	65	31	4					Brown and Haas 1978
Rawah (CO)	1977	Summer	54		94	73	7	3					Brown and Haas 1978
White Mountains (NH)	1977-78	Winter			45			8		50	28		Taylor and Mackoy 1980
Linville Gorge (NC)	1978	Summer/Fall	15	3	[3]89 [4]48	48	41	26	39				Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	5	5	[3]87 [4]42	48	43	3	25				Roggenbuck and others 1979
Joyce Kilmer/ Slickrock (NC)	1978	Summer/Fall	12	6	[3]91 [4]35	46	47	3	35				Roggenbuck and others 1979
Yosemite NP back-country (CA)	1978	Winter								92			Gilbert 1980
Baxter State Park (ME)	1979	Summer	23		[5]66 [6]51	68	[7]34 [8]67	1				15	Reiling and others 1981
Bob Marshall Wilderness complex (MT)	1982	Summer/Fall	57	16	68	61	28	1	17			15	Lucas 1985b

[1]Other includes such activities as horseback riding, river rafting, and camping.
[2]Day trips only.
[3]Hiking on trails.
[4]Hiking off trails.
[5]Mountain hiking.
[6]Gentle terrain hiking.
[7]Birdwatching.
[8]Other wildlife observation.

strongly influences the amount, nature, and distribution of use. Some swamp and lowland wildernesses in the Southeast receive almost no use. (Bradwell Bay in Florida is an example.) Water areas like the Boundary Waters Canoe Area Wilderness and several wildernesses with whitewater rivers have extremely high canoe or boat use and relatively little horse or hiking use. Outfitting is common in these lake and river wildernesses. While off-trail use is low everywhere, it is much higher in alpine areas with trail systems that take visitors above timberline. Finally, the nature of the resource largely explains the extent of such wilderness activities as hunting, fishing, rock climbing, and swimming.

Presence of Attractions.—The presence of attractions such as lakes, mountain peaks, views, and rock climbing opportunities within a wilderness affects the total number of visitors, where visitors go, and what they do. Some wilderness areas in the East and Midwest, regions of high population concentrations, have low use. While reasons for lack of visitation are largely unknown, their lack of special attractions is a likely cause. These areas have apparent naturalness, but they may be "ordinary woods" in the minds of potential visitors. The concentration of travel and camping use around lakes, rivers, views, and ridgelines is common throughout wilderness. This is especially the case in small areas with only a single or a few attractions.

Managing Agency.—Research suggests limited differences in patterns of National Forest and National Park wilderness visitors. National Park visitors are more likely to be alone, to travel in small parties, and they do not

hunt (with limited exceptions in Alaska). There are almost certainly fewer horse users in the parks, but we found no data to substantiate this.

Time of Establishment as Wilderness.—The relatively low use of many recently established wilderness areas in the East, Midwest, and West may be due to their lower scenic quality or the presence of fewer attractions, but it may also be that the new areas have not yet become widely known. Several of these areas were designated "wilderness" not so much because of their current recreational popularity, but because of their apparent naturalness, opportunities for solitude, and their potential for providing a more complete ecosystem representation within the Wilderness System.

Extent of Area Access.—Type and degree of access to the wilderness influence amount, nature, and distribution of area use. Most island wildernesses have little or no use, either because there is no public access or because access is strictly controlled. Some wildernesses—the Great Bear and the Frank Church-River of No Return Wildernesses—have airfields within or adjacent to them, and this affects their kind of use and users. Perhaps most important, the kind of access to individual trailheads strongly influences the amount of use that the entry points and their trails receive. Entry points reached only after travel for long distances on dusty, gravel roads filled with "chuck holes" tend to receive less use than those reached over short, good roads.

Time (Season and Year).—As might be expected, season of the year substantially affects amount of use. For virtually all wilderness areas, summer is the season of highest use. But season of use also influences what people do in wilderness, method of travel, weekly pattern of use, and length of stay. Hunting is a fall activity almost everywhere. Because of the large number of hunters, fall has the highest proportion of horse users. Length of stay tends to be somewhat longer in fall but shorter in winter. Winter activities include cross-country skiing and snowshoeing, and peaking of weekend use seems even more severe in winter than in other seasons.

Trail System Configuration.—Since virtually all wilderness users stick to established trails, the trail system has a strong influence on where people travel and where they camp. Some wildernesses have a single trail that leads from an entry point to an area attraction, with few branching alternative routes. Such trails tend to become heavily used, two-way traffic corridors. Other areas have multiple trails that converge at a single point. Such points, especially at attractions, tend to become popular for eating, resting, and camping.

Type of User.—The type of user—hiker or horse user, day-user or camper, hunter or nonhunter—is significantly related to wilderness use patterns. Horse users come in larger groups, stay longer, and penetrate deeper into the wilderness than hikers do. Horse travelers also are more likely to hunt and take photos, while hikers are more likely to engage in swimming and nature study. Hunters are predominantly horse users, and are more likely to be outfitted, come in the fall, and stay longer. Campers are more likely than day-users to be horse users, travel in larger groups, and engage in more activities. River rafters tended to visit the wilderness in large groups and be outfitted.

Tradition.—Finally, while no hard data are available to substantiate the idea, some wilderness areas seem to have certain users because they traditionally have had those uses. The Bob Marshall has the image of a horse area; the Boundary Waters Canoe Area is perceived as a canoe area. Perhaps because of past use histories or images in the minds of potential users, these areas continue to attract traditional user groups.

User Characteristics

Age.—Wilderness users tend to be young, younger than the general population. Table 8 indicates that there is a substantial overrepresentation of 16- to 25-year-olds and 26- to 35-year-olds among wilderness visitors compared to the general population in virtually all wilderness areas studied. However, the 36-45 age group is also overrepresented in most areas, and the 46-55 age category is common in wilderness, being present in proportions similar to their numbers in the general population. When wilderness allocation decisions are debated, opponents often argue that wilderness designation denies access to the old and the young (Lucas 1980). Table 8 suggests that the 56 and older age groups are substantially underrepresented, but older people have lower participation rates in all types of outdoor recreation (Bureau of Outdoor Recreation 1972). Older people do visit wilderness. For example, 10, 11, and 12 percent of the 1970 wilderness visitors in the Bob Marshall, Selway-Bitterroot, and Great Bear Wildernesses, respectively, were 56 years or older. While table 8 suggests that young children are substantially underrepresented in most wildernesses, this is in part an artifact of data collection methods. Typically, the referenced surveys did not include children under about 16 years of age. Lucas (1980) reported that about half of all wilderness user groups in the nine areas he studied contained children.

The few studies done in the East and Southeast suggest age distributions similar to those in the Rockies and the Pacific Northwest. If anything, users in the East are slightly younger. Lucas (1980) reported little association between season of visit and age of visitor, but his data generally reflect studies of only summer and fall users. While data are almost nonexistent, research in the Great Smoky Mountains National Park backcountry and in the White Mountains of New Hampshire suggests that winter users are younger. Finally, Lucas (1980) found that horse users were somewhat older than hikers and campers were somewhat younger than day-users in the nine western areas he studied.

Gender.—Table 8 indicates most wilderness visitors are males; percentages typically range from 70 to 85 percent. In smaller, hiking-oriented areas, the number of males is often at the lower end of this range; but in the larger, horse-oriented areas, percentages are at the upper end (Hendee and others 1978). Lucas (1980) indicated that for the fall season, particularly in popular hunting wildernesses, the percentages of males are even higher. The limited data on winter wilderness visitors are mixed. Hughes (1985) surveyed almost no women in the backcountry of Great Smoky Mountains National Park during her winter use study, but Snowden (1976) and Taylor and Mackoy (1980) found the proportion of winter female

Table 8.—Age and gender of wilderness visitors[1]

Wilderness area (State)	Year	Season	Age (percent of total) 1-15	16-25	26-35	36-45	46-55	56-64	65+	Percent male	Source
Boundary Waters Canoe Area (MN)[2]	1960	Summer	30	42	13	13		2		82	Lucas 1964
Glacier Peak (WA), Eagle Cap (OR), and Three Sisters (OR)	1965	Summer	3	21	24	23	21	5	2	82	Hendee and others 1968
Bob Marshall (MT)	1970	Summer/Fall	13	17	21	25	13	10		80	Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	8	40	22	12	12	6		70-80	Hendee and others 1978
Great Bear (MT)	1970	Summer/Fall	0	7	30	32	18	12		87	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	9	24	25	20	14	9		70-80	Hendee and others 1978
Spanish Peaks (MT)	1970	Summer/Fall	26	29	17	17	9	3		70-80	Hendee and others 1978
Scapegoat (MT)	1970	Summer/Fall	4	29	25	24	11	8		70-80	Hendee and others 1978
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	0	50	20	15	9	6		70	Murray 1974
Selway-Bitterroot (ID & MT)	1971	Summer/Fall	4	27	24	19	14	11		70-80	Hendee and others 1978
Desolation (CA)	1972	All year	29	28	18	12	10	2		—	Hendee and others 1978
Great Smoky Mountains NP backcountry (NC & TN)	1973	Summer	0	34	31	19	16			92	Burde and Curran 1986
Adirondack High Peaks	1960	Summer								83	Snowden 1976
(NY)	1974-75	Winter								78	Snowden 1976
Eagles Nest (CO)	1977	Summer	62			37			1	78	Brown and Haas 1978
Rawah (CO)	1977	Summer	76			22			1	79	Brown and Haas 1978
Weminuche (CO)	1977	Summer	61			37			1	80	Brown and Haas 1978
Popo Agie (WY)	1978	Summer	7	78		14		1		75	Manfredo 1978b
Bridger (WY)	1978	Summer	17	71		10		3		72	Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	1	74		20		5		72	Manfredo 1978b
Linville Gorge (NC)	1978	Summer/Fall	11	31	37	13	7			73	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	12	27	32	16	13			75	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC & TN)	1978	Summer/Fall	10	34	36	12	8			69	Roggenbuck and others 1979
White Mountains (NH)	1977-78	Winter	0	32	37	19	8	4		74	Taylor and Mackoy 1980
	?	Summer	0	37	29	17	10	6		64	Taylor and Mackoy 1980
Great Smoky Mountains NP backcountry (NC & TN)	1979	Winter	0	38	45	10	6	2	0	99	Hughes 1985
Baxter State Park (ME)	1979	Summer	22	30	25	10	6	7		?	Reiling and others 1981
Bob Marshall (MT)	1982	Summer/Fall	13	18	24	23	22			70	Lucas 1985b
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer	0	34	38	15	9	4		89	Burde and Curran 1986
U.S. population	1960		33	13	13	12	12	8	9		U.S. Census
	1970		31	17	12	11	11	18			U.S. Census
	1978		25	19	15	11	10	20			Reiling and others 1981

[1]Age data on wilderness visitors and U.S. population were interpolated to fit table's age categories.
[2]Data are for paddle canoeists.

Table 9.—Education level distribution as a percent of total wilderness visitors by area

<table>
<tr><th rowspan="2">Wilderness area (State)</th><th rowspan="2">Year</th><th rowspan="2">Season</th><th colspan="6">Years of schooling completed</th><th rowspan="2">Source</th></tr>
<tr><th>0-8</th><th>9-11</th><th>12</th><th>13-15</th><th>16</th><th>17+</th></tr>
<tr><td>Boundary Waters Canoe Area (MN)[1]</td><td>1960</td><td>Summer</td><td>0</td><td colspan="2">21</td><td colspan="2">54</td><td>25</td><td>Lucas 1964a</td></tr>
<tr><td>Glacier Peak (WA)</td><td>1965</td><td></td><td colspan="3">35</td><td colspan="2">36</td><td>29</td><td>Hendee and others 1968</td></tr>
<tr><td>Eagle Cap (OR)</td><td>1965</td><td></td><td colspan="3">38</td><td colspan="2">38</td><td>24</td><td>Hendee and others 1968</td></tr>
<tr><td>Three Sisters (OR)</td><td>1965</td><td></td><td colspan="3">36</td><td colspan="2">34</td><td>30</td><td>Hendee and others 1968</td></tr>
<tr><td>High Sierra (CA)</td><td>1960</td><td></td><td colspan="3">18</td><td colspan="2">49</td><td>33</td><td>Hendee and others 1968</td></tr>
<tr><td>Bob Marshall (MT)</td><td>1970</td><td>Summer/Fall</td><td>4</td><td>14</td><td>22</td><td>17</td><td>11</td><td>31</td><td>Lucas 1980</td></tr>
<tr><td>Cabinet Mountains (MT)</td><td>1970</td><td>Summer/Fall</td><td>3</td><td>22</td><td>26</td><td>24</td><td>8</td><td>15</td><td>Lucas 1980</td></tr>
<tr><td>Great Bear (MT)</td><td>1970</td><td>Summer/Fall</td><td>3</td><td>6</td><td>29</td><td>15</td><td>24</td><td>24</td><td>Lucas 1980</td></tr>
<tr><td>Mission Mountains (MT)</td><td>1970</td><td>Summer/Fall</td><td>4</td><td>14</td><td>15</td><td>16</td><td>12</td><td>35</td><td>Lucas 1980</td></tr>
<tr><td>Spanish Peaks (MT)</td><td>1970</td><td>Summer/Fall</td><td>2</td><td>10</td><td>21</td><td>26</td><td>8</td><td>30</td><td>Lucas 1980</td></tr>
<tr><td>Scapegoat (MT)</td><td>1970</td><td>Summer/Fall</td><td>4</td><td>13</td><td>30</td><td>24</td><td>9</td><td>18</td><td>Lucas 1980</td></tr>
<tr><td>Appalachian Trail (Southern NF's)</td><td>1970-71</td><td>Summer/Fall</td><td colspan="3">20</td><td colspan="2">44</td><td>36</td><td>Murray 1974</td></tr>
<tr><td>Selway-Bitterroot (MT & ID)</td><td>1971</td><td>Summer/Fall</td><td>3</td><td>10</td><td>27</td><td>23</td><td>9</td><td>27</td><td>Lucas 1980</td></tr>
<tr><td>Desolation (CA)</td><td>1972</td><td>All year</td><td>0</td><td>5</td><td>12</td><td>29</td><td>11</td><td>42</td><td>Lucas 1980</td></tr>
<tr><td>Cranberry back-country (WV)</td><td>1972</td><td>Spring/ Summer/Fall</td><td colspan="2">22</td><td>41</td><td>15</td><td colspan="2">22</td><td>Echelberger and Moeller 1977</td></tr>
<tr><td>Adirondack High Peaks (NY)</td><td>1960</td><td>Summer</td><td colspan="3">16</td><td colspan="2">57</td><td>22</td><td>Snowden 1976</td></tr>
<tr><td></td><td>1974-75</td><td>Winter</td><td colspan="3">19</td><td colspan="2">53</td><td>28</td><td></td></tr>
<tr><td>Weminuche (CO)</td><td>1977</td><td>Summer</td><td>1</td><td>6</td><td>14</td><td>24</td><td>18</td><td>39</td><td>Brown and Haas 1978</td></tr>
<tr><td>Rawah (CO)</td><td>1977</td><td>Summer</td><td>0</td><td>6</td><td>11</td><td>24</td><td>25</td><td>34</td><td>Brown and Haas 1978</td></tr>
<tr><td>Eagles Nest (CO)</td><td>1977</td><td>Summer</td><td>0</td><td>2</td><td>10</td><td>27</td><td>26</td><td>33</td><td>Brown and Haas 1978</td></tr>
<tr><td>Yosemite NP backcountry (CA)</td><td>1978</td><td>Winter</td><td></td><td></td><td></td><td colspan="3">92</td><td>Gilbert 1980</td></tr>
<tr><td>Linville Gorge (NC)</td><td>1978</td><td>Summer/Fall</td><td colspan="2">1</td><td>15</td><td>27</td><td>20</td><td>37</td><td>Roggenbuck and others 1979</td></tr>
<tr><td>Shining Rock (NC)</td><td>1978</td><td>Summer/Fall</td><td colspan="2">3</td><td>19</td><td>26</td><td>21</td><td>31</td><td>Roggenbuck and others 1979</td></tr>
<tr><td>Joyce Kilmer/Slickrock (NC)</td><td>1978</td><td>Summer/Fall</td><td colspan="2">0</td><td>14</td><td>25</td><td>19</td><td>41</td><td>Roggenbuck and others 1979</td></tr>
<tr><td>Baxter State Park (ME)[2]</td><td>1979</td><td>Summer</td><td colspan="2">2</td><td>15</td><td>18</td><td>22</td><td>43</td><td>Reiling and others 1981</td></tr>
<tr><td>Bob Marshall Complex (MT)</td><td>1982</td><td>Summer/Fall</td><td>2</td><td>7</td><td>22</td><td>23</td><td>21</td><td>26</td><td>Lucas 1985b</td></tr>
<tr><td>U.S. population</td><td>1960</td><td></td><td colspan="3">92</td><td colspan="3">8</td><td>Hendee and others 1968</td></tr>
<tr><td></td><td>1970</td><td></td><td>28</td><td>17</td><td>34</td><td>10</td><td colspan="2">11</td><td>U.S. Census</td></tr>
<tr><td></td><td>1980</td><td></td><td>17</td><td>14</td><td>37</td><td>15</td><td colspan="2">17</td><td>U.S. Census</td></tr>
</table>

[1]Data represent paddling canoeists.
[2]Education level of head of household.

visitors in their eastern study areas to be similar to proportions in other seasons of the year. The 20 to 25 percent women found in most studies do, however, represent a significant minority in wilderness. Numbers of women may be increasing. For example, Lucas (1985b) reports that the proportion of female visitors to the Bob Marshall Wilderness grew from 20 percent in 1970 to 30 percent in 1982.

Education.—The most distinguishing characteristic of wilderness users is their high education level. As table 9 indicates, at least 25 percent of the visitors to most areas studied either are attending or have attended graduate school. In most areas, about 40 percent have completed college; in some areas this number exceeds 50 percent. This far exceeds the schooling for the United States general population, where 11 and 18 percent completed college or attended graduate school in 1970 and 1980, respectively. In most areas the proportion of wilderness visitors going to school beyond college is greater than the proportion of the U.S. population that goes beyond high school (Lucas 1980). Also, the difference between wilderness visitors and the general population is even larger than these figures suggest, for the U.S. census data are based on education levels of people 25 or more years of age. Wilderness surveys generally include individuals down to 16 years old. Many of these are students and have not yet completed their schooling, so their education attainment usually is lower than it would be at 25.

Education levels vary a great deal among study areas, but all are much higher than both the national average and the average for their State. Variation across areas seems due in part to the time of the study (with the higher educational levels of areas studied most recently reflecting the growing educational levels in the country), the overall education levels of the area's State (thus the large number of visitors to Desolation Wilderness, CA, with graduate education), and the educational levels of nearby communities. Montana areas with adjacent small forest industry towns have visitors with lower educational levels than wildernesses near university towns (Lucas 1980). Educational levels also vary with other wilderness

Table 10.—Occupational distribution as a percent of total wilderness visitors by area

Wilderness area (State)	Year	Occupation: Professional and technical	Business manager	Craftsman and operations	Farmer	Clerical, sales, and service worker	Military	Housewife	Student	Other	Source
Boundary Waters Canoe Area (MN)[1]	1960	71	13	2	1	7				6	Lucas 1964a
Bob Marshall (MT)	1964	18	28	3		15	9		27		Merriam and Ammons 1967
Mission Mountains (MT)	1964	49	7	4		16			22	2	Merriam and Ammons 1967
Glacier NP back-country (MT)	1964	39	16			13			32		Merriam and Ammons 1967
Bob Marshall (MT)	1970	32	11	15	3	9	2	9	17	2	Lucas 1980
Cabinet Mountains (MT)	1970	20	2	16	2	7	2	9	31	11	Lucas 1980
Great Bear (MT)	1970	33	5	14	5	11	1	9	4	8	Lucas 1980
Mission Mountains (MT)	1970	41	2	15	2	5	0	9	20	5	Lucas 1980
Spanish Peaks (MT)	1970	31	5	10	5	8	1	7	34	2	Lucas 1980
Scapegoat (MT)	1970	23	6	10	6	9	7	9	26	4	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	60	17		6			12		5	Murray 1974
Selway-Bitterroot (MT & ID)	1971	26	4	14	5	10	0	9	22	10	Lucas 1980
Desolation (CA)	1972	39	1	7	0	11	3	1	30	8	Lucas 1980
Linville Gorge (NC)	1978	47	14	5	0	11		1	17	5	Roggenbuck and others 1979
Shining Rock (NC)	1978	29	29	9	1	12		2	10	8	Roggenbuck and others 1979
Joyce Kilmer/ Slickrock (NC)	1978	42	13	8	1	14		3	14	5	Roggenbuck and others 1979
Cranberry back-country (WV)	1972	36			40				24		Echelberger and Moeller 1977
Adirondack High Peaks (NY)	1974-75	35	5			3			43	14	Snowden 1976
White Mountains (NH)	1977-78	36	10						31	24	Taylor and Mackoy 1980
Bob Marshall complex (MT)	1982	37	8	18	5	10	2	4	11	5	Lucas 1985b
U.S. population	1958	9	12	17	6	12				44	
	1970	6	3	22	3	28	1	25	5	7	
	1980	9	7	21	2	23	1	21	4	12	

[1]Data represent paddle canoeists.

user characteristics. Day-users were slightly more educated than campers, and nonhunters had higher education levels than hunters in the Bob Marshall Wilderness complex (Lucas 1985b). More generally, hikers were more educated than horseback riders or river rafters, and summer visitors were more educated than fall visitors (Lucas 1980, 1985b).

Occupation.—Persons in the professional and technical occupations and students were the majority of visitors to most areas (table 10). In many areas 30 to 40 percent of all visitors were professional or technical workers, and from 20 to 30 percent were students. Professionals in wilderness exceeded the proportion in the U.S. population by four to five times, and students were four to seven times more numerous in wilderness than in the population. Housewives and clerical, sales, and service workers (many of whom are female) were the most underrepresented in wilderness. These patterns reflect the education and gender distribution of wilderness visitors discussed earlier.

Hikers were more likely to be professionals, technical workers, or students than were horse users. In contrast, horse travelers were much more likely to be "blue collar" craftsmen, laborers, and in some areas, farmers. Students formed a larger proportion of wilderness campers than of day-users. Finally, professional and technical workers and housewives were relatively more common in the summer than in the fall. Winter users were most likely to be students.

Table 11.—Distribution of family income as a percent of total wilderness visitors by area

Wilderness area (State)	Year	Season	Income (dollars) <5,000	5,000-9,999	10,000-14,999	15,000-24,999	25,000-49,999	50,000+	Source
Boundary Waters Canoe Area (MN)[1]	1960	Summer	27	45	19	3	6	0	Lucas 1964a
Bob Marshall (MT)	1970	Summer/Fall	6	30	23	29	14		Lucas 1980
Cabinet Mountains (MT)	1970	Summer/Fall	12	45	28	12	4		Lucas 1980
Great Bear (MT)	1970	Summer/Fall	9	19	22	30	20		Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	15	32	26	16	11		Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	17	29	26	17	11		Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	11	42	29	14	7		Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	10	24	23	44			Murray 1974
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	12	37	25	17	10		Lucas 1980
Desolation (CA)	1972	All year	11	24	19	35	11		Lucas 1980
Cranberry backcountry (WV)	1972	Spring/ Summer/Fall	12	32	35	21			Echelberger and Moeller 1977
Four California Wilderness Areas (CA)[2]	1973		27	15	18	26	14		Hendee and others 1978
Adirondack High Peaks (NY)	1974-75	Winter	10	19	23	27	17	4	Snowden 1976
White Mountains (NH)	1977-78	Winter	5	12	20	26	30	7	Taylor and Mackoy 1980
Baxter State Park (ME)	1979	Summer	16		14	33	37		Reiling and others 1981
U.S. Population	1960 families		42	43	11	3	1	0.1	U.S. Department of
	1970 families		19	32	27	18	4	0.5	Commerce, 1983
	1980 families		6	13	14	28	32	7	(Statistical Abstract 1982-83)

[1]Data represent paddle canoeists.
[2]Specific areas unidentified.

In Lucas' (1985b) comparative study of visitors to the Bob Marshall Wilderness complex, he found such professional workers as accountants, engineers, doctors, nurses, teachers, religious workers, and scientists to be even more common in 1982 than in 1970. Farmers and craftsmen were also slightly more frequent, and, somewhat surprisingly, the percentage of students and housewives had dropped.

Income.—As a group, wilderness visitors have above average incomes (as do most outdoor recreationists) (table 11). This reflects the high education levels and the high proportion of users with professional occupations. There is, however, considerable variation by area. Some areas (such as the Mission Mountains, Spanish Peaks, Scapegoat, Selway-Bitterroot, and Cranberry), have visitors with incomes close to the national average, but others far exceed it. Most eastern area users have high incomes compared to the general U.S. population, as do Desolation visitors in California. These differences reflect the variation in the population's income in the States in which areas are located. Thus, many Montana visitors reflect the country's national income average, but they still exceed their State's average. In some instances, higher than average income figures are in part the result of comparing user incomes in the late 1970's with a 1970 standard. Also, some areas' high incomes result from the type of user they attract. For example, Great Bear is an area with considerable airplane access and the Bob Marshall has heavy horse and outfitter use (Lucas 1980); these uses may be beyond the means of lower income people. The few studies of winter wilderness users suggest high incomes for them as well.

These high income figures have led some to suggest that wilderness is accessible only to the very wealthy. This, however, is not supported by the data. For most areas studied in 1970, from one-third to one-half of all users had annual incomes below $10,000, at a time when the median U.S. income was about $9,000 (Lucas 1980). In addition, it usually costs little to actually use wilderness. Most visitors travel only relatively short distances to reach their wilderness destination (Lucas 1980), and costs per wilderness use-day in the early 1970's were usually low—only about $10 (Hendee and others 1978).

Place of Residence.—Visitors to most wilderness areas are from the State in which the area is located (table 12). In the West, except for the nationally known Glacier National Park backcountry and Colorado's Weminuche Wilderness (located in close proximity to Utah, Arizona, and New Mexico), more than half of all areas' visitors were in-State residents. For many areas, State residents exceeded 75 percent. For California areas, the number was 84 percent or higher. In addition, Lucas (1985b) found that most resident visitors come from the State's regions closest to the wilderness. For example, 60 percent of all visitors to the Bob Marshall Wilderness complex were from Montana, and 54 percent of all its visitors were from northwestern Montana—the region where the areas are located. Thus, in the West, it appears that wilderness recreational benefits are primarily regional in nature.

Table 12.—Area of residence and membership in wilderness, conservation, and outdoor clubs as a percent of total visitors by area

Wilderness area (State)	Year	Season	Visitor residence In-State[1]	Out-of-State	Urban	Rural	Club membership	Source
Boundary Waters Canoe Area (MN)[2]	1960	Summer	46	54				Lucas 1964a
Bob Marshall (MT)[3]	1964	Summer/Fall	68	32				Merriam and Ammons 1967
Mission Mountains (MT)[3]	1964	Summer/Fall	80	20				Merriam and Ammons 1967
Glacier NP back-country (MT)	1964	Summer/Fall	19	81				Merriam and Ammons 1967
Glacier Peak (WA)	1965	Summer					25	Hendee and others 1968
Eagle Cap (OR)	1965	Summer					32	Hendee and others 1968
Three Sisters (OR)	1965	Summer					32	Hendee and others 1968
Allagash Wilderness	1966		63	37				Cieslinski 1980
Waterway (ME)	1973	All year	48	52				Cieslinski 1980
	1978		51	49				Cieslinski 1980
Bob Marshall (MT)	1970	Summer/Fall	64	36	65	35	30	Lucas 1980
	1982	Summer/Fall	57	43	61	39	25	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	75	25			24	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	53	47			38	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	74	26			27	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	71	29			28	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	86	14			26	Lucas 1980
Selway-Bitterroot (MT & ID)	1970	Summer/Fall	64	36			27	Lucas 1980
Desolation (CA)	1972	All year	93	7			35	Lucas 1980
Appalachian Trail (Southern NF's)	1970-71	Summer/Fall	49	51	68	32		Murray 1974
Yosemite NP back-	1973	?	84	16				van Wagtendonk 1981
country (CA)	1976	Summer	12	88				Leonard and others 1978
Great Gulf (NH)								
Indian Peaks back-	1976	Summer	77	23				Haas 1978a
country (CO)	1976-77	Winter	96	4				Haas 1978a
Weminuche (CO)	1977	Summer	33	66	84	15		Brown and Haas 1978
Rawah (CO)	1977	Summer	72	26	87	14		Brown and Haas 1978
Eagles Nest (CO)	1977	Summer	75	22	79	20		Brown and Haas 1978
White Mountains (NH)	1977-78	Winter	27	74			54	Taylor and Mackoy 1980; Taylor and Spencer 1980
Linville Gorge (NC)	1978	Summer/Fall			67	33	38	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall			68	32	38	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall			77	23	57	Roggenbuck and others 1979
Baxter State Park (ME)	1979	Summer	52	48				Reiling and others 1981
Great Smoky Mountains NP	1979	Summer	35	65				Hughes 1985
backcountry (NC & TN)		Winter	46	54				Hughes 1985
Great Bear (MT)	1982	Summer/Fall	63	37	57	43		Lucas 1985b
Scapegoat (MT)	1982	Summer/Fall	64	38	67	33		Lucas 1985b

[1]In-State means visitor resides in area's State(s).
[2]Data for paddle canoeists.
[3]Figures estimated from report's bar graphs.

In the East, many more wilderness visitors were from out of State. This likely reflects both the smaller size of eastern States and the relative scarcity of wilderness resources there. These areas are highly accessible, and demand is high.

Lucas (1980) reported mixed results when he related place of residence to other wilderness use and user characteristics. He expected that horseback travelers, fall visitors, and overnight visitors would more often be out-of-State visitors. In his 1970 study of the Bob Marshall complex, he found more horse users (41 percent) than hikers (30 percent), more hunters (42 percent) than nonhunters (29 percent), and more campers (34 percent) than day-users (16 percent) to be from out of State. In the 1970 sample there were no out-of-State river rafters. By 1982, user characteristics had changed. Out-of-State horse users and hikers represented about an equal proportion within their use category (about 40 percent), and out-of-State raft use had reached 27 percent. The percent of nonresident hunters remained the same (42 percent), but the percent of out-of-State nonhunters grew to 39 percent. Percentages of nonresident campers and day-users grew to 42 and 29, respectively, in the 1982 study.

Urban/Rural Residence.—Most wilderness visitors live in urban areas. Table 12 indicates that for the areas for which data are available, more than 60 percent of all wilderness users reside in urban areas. Brown and Haas (1978) reported that about 80 percent of visitors to three Colorado areas they studied were urban residents. Lucas (1980) reported a range of 45 to 90 percent urban resi-

dents for the nine western areas he studied. Of these, Desolation Wilderness in California had the most urban clientele, and the Great Bear and Cabinet Mountains had the least. In most areas studied (Lucas 1980, 1985b), hikers and rafters were substantially more urban than horsemen, and hunters were less urban than nonhunters.

The high amount of use of wilderness by urbanites does not, however, suggest that wilderness users are disproportionately urban. Most of the U.S. population (about 74 percent) is urban, and urban residents appear to use wilderness in proportions about equal to their numbers of the general population. For example, Lucas (1985) found that 50 percent of the Montana visitors to the Bob Marshall complex were from urban areas; 51 percent of Montana population is urban. At the same time, 74 percent of the area's out-of-State visitors were urban residents, a proportion equal to that of the urban population of the United States.

Club Membership.—Some have suggested that wilderness visitors are predominantly members of specialized interest groups such as wilderness, conservation, and outdoor recreation clubs. Research refutes this contention. For most areas for which data are available, only 20 to 35 percent of the users belong to any sort of outdoor club (table 12). In the East, these percentages seem somewhat higher. For example, over 50 percent of both winter recreationists in the White Mountains backcountry and the visitors to Joyce Kilmer-Slickrock Wilderness belong to a conservation or recreation club. This likely reflects the unusually high educational levels, incomes, and urban nature of the areas' visitors.

Lucas (1980) examined the type of outdoor club to which members belonged, and found considerable variation across areas. In many areas, visitors belonged primarily to local rod and gun clubs. For example, only about 28 percent of the club members among visitors to the Bob Marshall Wilderness complex belonged to a wilderness-oriented club (Lucas 1985b). In contrast, over half of the outdoor club members among visitors to the Desolation and Mission Mountains Wildernesses and the Spanish Peaks Primitive Area belonged to a national wilderness-oriented organization like the Sierra Club or The Wilderness Society. Lucas (1985b) also found that Bob Marshall horsemen were more likely to be club members than were hikers. Also, while hunters and nonhunters in the Bob Marshall were similar in percentage of outdoor club membership, hunters were less likely to be members of wilderness organizations and more likely to belong to rod and gun clubs.

Previous Wilderness Experience.—As table 13 indicates, most wilderness users have considerable experience. For the western areas, between 70 and 90 percent of visitors had made at least one previous visit to a wilderness or wildernesslike area. These percentages were slightly lower for some eastern areas. The amount of previous experience in the study area varied a great deal. For many areas, about 30 or 40 percent had made no previous visits to the study area, but in some wildernesses, this number reached 60 percent. The areas with the high percentage of first-time users tended to be those that had been designated as wilderness more recently. Many areas also had between 20 and 30 percent of their visitors who had made six or more visits. These percentages dropped to 10 to 20 for some more recently established areas.

Lucas (1980) and Hendee and others (1968) have also reported age of first visit to wilderness, the average number of visits to wilderness per year, and number of days spent in wilderness for several western wilderness areas. Typically, between one-third and one-half of the wilderness users made their first visit before their 16th birthday. Parents were important in introducing their children to wilderness, but more often visitors first went to wilderness with a friend or organization. The parents' influence might be greatest through their car camping practices. Between 50 and 60 percent of the wilderness visitors studied said their parents took them car camping when they were young. In comparison, only about 20 percent of the national population car camps.

Visitors averaged three or four wilderness visits per year, and spent a total of 6 to 10 days in wilderness (Lucas 1980). This suggests fairly frequent and fairly short trips. Hikers in the Bob Marshall Wilderness complex tended to make more trips each year than horse users, but their trips were shorter (Lucas 1985b). Hikers also were more experienced, and were introduced to wilderness at a younger age.

Type of Group.—Wilderness user groups composed of the family or family and friends make up the majority of all groups in virtually all areas (table 14). An exception to this are users of the three wilderness areas studied in western Wyoming (Manfredo 1978b); here, classes from the National Outdoor Leadership School contribute to low proportions of families. About half of all groups contain children. Family groups by themselves often account for about 40 percent of all groups. The second most frequent user group overall—and the most frequent in Montana's Great Bear, Wyoming's Popo Agie, Bridger, and Fitzpatrick Wildernesses, and Great Smoky Mountains National Park backcountry—are groups of friends. Organized groups or clubs like outing clubs, Boy Scout or Girl Scout groups, or church groups generally make up 10 percent or less of all groups. In many areas such groups account for less than 5 percent. The percentage of visitors who are alone varies somewhat by area, but in most places is less than 10 percent. In some areas, almost no one travels alone. Exceptions are user groups in the Great Smoky Mountains, Eagles Nest in Colorado, and the Popo Agie, Bridger, and Fitzpatrick in Wyoming, where between 10 and 20 percent are alone.

The patterns of type of group vary by method of travel, day or overnight use, and season of use (Lucas 1985b). In the Bob Marshall Wilderness complex the few solitary visitors are more likely to be hikers than horse users. Summer visitors were twice as likely to be alone, and day-users in the wilderness complex were more likely groups of friends, but by 1982 the proportion of family groups and groups of friends was similar for horse users and hikers. Groups of friends were more numerous in fall in the 1970 study, but by 1982, family groups were as common in the fall as in the summer. These figures and trends suggest that the predominance of the family is growing in wilderness, that family use is spreading more uniformly across seasons and travel patterns, and that strengthened family ties may be an increased benefit of wilderness.

Table 13.—Previous wilderness experience as a percent of total visitors by area

Wilderness area (State)	Year	Season	Previous visits to wilderness	Previous visits to study area: 0	1-2	3-5	6+	Source
Boundary Waters Canoe Area (MN)[1]	1960	Summer			— 13 —			Lucas 1964a
Bob Marshall Wilderness complex (MT)	[2]1970	Summer/Fall	78	45	18	17	20	Lucas 1980
	[2]1982	Summer/Fall	78	56	16	14	14	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	85	37	17	13	33	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	75	61	13	7	19	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	80	45	21	13	21	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	81	50	17	10	23	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	73	61	17	9	13	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	76	43	13	14	30	Lucas 1980
Desolation (CA)	1972	All year	89	30	23	17	30	Lucas 1980
Cranberry backcountry (WV)	1972	Spring/ Summer/Fall			— 75 —			Echelberger and Moeller 1977
Adirondack High Peaks (NY)	1974-75	Winter	70	0	59	24	17	Snowden 1976
Indian Peaks back-country (CO)[3]	1976	Summer		51	24	14	11	Brown and others 1977
Weminuche (CO)[3]	1977	Summer		30	— 54 —		16	Haas 1978b
Eagles Nest (CO)[3]	1977	Summer						Manfredo and Haas 1978
Dillon District[4]				45	22	23	10	
Holy Cross District[4]				31	20	28	21	
Rawah (CO)[3]	1977	Summer		60	20	6	4	Manfredo 1978a
Linville Gorge (NC)	1978	Summer/Fall	66	39	11	18	33	Roggenbuck and others 1979
Shining Rock (NC)	1978	Summer/Fall	43	35	14	21	30	Roggenbuck and others 1979
Joyce Kilmer/Slickrock (NC)	1978	Summer/Fall	82	60	12	19	9	Roggenbuck and others 1979
Popo Agie (WY)[3]	1978	Summer		55	30	10	5	Manfredo 1978b
Bridger (WY)[3]	1978	Summer		62	23	8	7	Manfredo 1978b
Fitzpatrick (WY)[3]	1978	Summer		78	16	3	3	Manfredo 1978b
Maroon Bells-Snowmass (CO)[3]	1978	Summer		68	21	— 11 —		Haas and others 1982
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer		34	24	13	28	Burde and Curran 1986

[1]Data represent paddle canoeists.
[2]Bob Marshall complex includes the Bob Marshall, Great Bear, and Scapegoat Wildernesses.
[3]Experience levels refer to visits to the study area within the past 12 months.
[4]Previous visits categories are 0, 1, 2-6, 7+.

Wilderness Knowledge

Research to determine the knowledge base of wilderness visitors and the general public is scarce. This knowledge may influence attitudes and, especially, behavior concerning wilderness and has important implications for understanding wilderness use and managing it.

There are a few studies that provide information on three types of knowledge relative to wilderness: (1) wilderness definitions, (2) appropriate practices in wilderness and related regulations, and (3) the natural role of wildfire. There is apparently no research on public knowledge of alternative wilderness or similar nonwilderness opportunities, or alternative locations within a particular wilderness, although there have been several studies of how visitors respond to information about various parts of a wilderness (Schomaker 1975; Lime and Lucas 1977; Lucas 1981; Roggenbuck and Berrier 1981; Krumpe and Brown 1982).

Wilderness Definitions.—In general, wilderness visitors have more accurate information about wilderness definitions than the general public has, and the public in areas close to a number of wildernesses has more accurate information than people who live far from wilderness. Young (1978) found that the general public in Illinois had little knowledge of the basic definitions of wilderness. Many were unaware that logging and mechanical recreation generally were banned. Keegan and others (1982) found higher knowledge of wilderness characteristics among the general public in Montana; 70 percent of those polled reported they had personally visited some of the State's many wildernesses. About 16 percent had visited a classified wilderness in the previous year, and about 40 percent had done so at some time.

Stankey (1973) and Robertson (1981) both found fairly high knowledge levels among wilderness visitors, although Stankey reported considerable variation among his four study areas.

Table 14.—Type of group as a percent of total groups by area

Wilderness area (State)	Year	Season	Type of group: Family	Family and friends	Friends	Organized group or club	Alone	Information missing	Source
Glacier Peak (WA), Eagle Cap (OR), Three Sisters (OR)	1965		—— 47 ——		38	8	7		Hendee and others 1968
Bob Marshall Wilderness	1970	Summer/Fall	43	15	30	2	6	4	Lucas 1980
complex (MT)	[1]1982	Summer/Fall	—— 55 ——		36	3	6	0	Lucas 1985b
Cabinet Mountains (MT)	1970	Summer/Fall	40	15	33	5	5	1	Lucas 1980
Great Bear (MT)	1970	Summer/Fall	24	14	62	0	0	0	Lucas 1980
Mission Mountains (MT)	1970	Summer/Fall	46	17	29	2	2	5	Lucas 1980
Spanish Peaks (MT)	1970	Summer/Fall	38	13	35	4	5	5	Lucas 1980
Scapegoat (MT)	1970	Summer/Fall	36	21	29	8	6	1	Lucas 1980
Selway-Bitterroot (MT & ID)	1971	Summer/Fall	40	14	37	3	5	1	Lucas 1980
Desolation (CA)	1972	All year	33	17	32	8	5	5	Lucas 1980
Boundary Waters Canoe Area (MN)	1974	Summer	—— 61 ——		27	11	1		Hendee and others 1978
Weminuche (CO)	1977	Summer	44	13	27	11	5		Haas 1978b
Eagles Nest (CO)	1977	Summer							Manfredo and Haas 1978
Dillon District			40	10	37	2	11		
Holy Cross District			28	8	40	4	20		
Rawah (CO)	1977	Summer	47	5	37	3	7		Manfredo 1978a
Popo Agie (WY)	1978	Summer	25	14	47		15		Manfredo 1978b
Bridger (WY)	1978	Summer	27	7	49		16		Manfredo 1978b
Fitzpatrick (WY)	1978	Summer	19	7	53		20		Manfredo 1978b
Maroon Bells-Snowmass (WY)	1978	Summer	42	10	37	1	10		Haas and others 1982
Baxter State Park (ME)	1979	Summer	—— [2]56 ——				3		Reiling and others 1981
			—— [3]51 ——				8		
Great Smoky Mountains NP backcountry (NC & TN)	1983	Summer	—— 40 ——		44		16		Burde and Curran 1986

[1]Bob Marshall complex includes Bob Marshall, Great Bear, and Scapegoat Wildernesses.
[2]Resident figures.
[3]Nonresident figures.

Appropriate Practices in Wilderness and Related Regulations.—McAvoy and Hamborg (1984) found Boundary Waters Canoe Area Wilderness visitors were quite knowledgeable about regulations in the area. Persons reporting the Forest Service as their main source of information had higher knowledge levels. Brochures were effective at communicating; personal contact added little. Robertson (1981) also found fairly high knowledge of recommended low-impact camping practices among visitors to the Three Sisters Wilderness in Oregon, and she found that knowledge predicted behavior far better than other variables tested.

Hill (1975) found limited knowledge of low-impact practices among University of Utah students who were beginning a class in backpacking skills. Littering behavior was the only topic about which students had good knowledge. Lucas (1985b) found an increase in Bob Marshall Wilderness complex visitors' knowledge about garbage handling (packing it out rather than burying it) from 1970 to 1982. In 1970, most visitors thought burying was appropriate, but by 1982 this practice was rejected by a 2 to 1 margin. Stankey (1979) reported that 40 percent of the 1973 visitors to the San Gorgonio and San Jacinto Wildernesses in California were unaware of a use rationing system instituted that same year.

The Natural Role of Wildfire.—Stankey (1976) found poor knowledge about wilderness fire and its effects, but similar to Robertson (1981), he found that support for a policy of allowing fire to more nearly play its natural role was associated with greater knowledge of fire. McCool and Stankey (1986) found that Selway-Bitterroot Wilderness visitors' knowledge of wilderness fires increased considerably from 1971 to 1984. The positive association of knowledge about fire and attitudes supporting prescribed fire found in the earlier study was confirmed for 1984 visitors.

Use Measurement

Reasonably accurate basic recreational use data are widely recognized as essential to professional management of most wildernesses. Despite the importance of use data, for years managers of many areas have made do with data of low accuracy.

Managers' Use Estimation Techniques.—Five general methods of estimating wilderness recreational use are commonly used by managers:

1. Casual observation and best guesses. Managers or fieldworkers try to recall how many visitors they saw, wherever and whenever they happened to be in or around the wilderness, and then conjure an estimate, usually using last year's reported use as a starting point. Use of this method is motivated by agency requirements for a report of use each year, not by any need to employ use data in management activity. This description may seem harsh, but this method has been one of the most commonly used systems throughout the last 20 years.

2. Recorded observation and systematic "guesstimates." Agency personnel keep notes of visitor numbers, particularly counts of parked cars at access points, usually when duties take them there, rather than on a planned sampling schedule. Some mathematical expansion factors are applied to the recorded observations to produce a use estimate.

3. Trail register data. Data from voluntary, unstaffed trail registers are summarized. Usually some expansion is made for nonregistration. However, registration behavior is usually not observed and an assumed rate is generally used. Often one expansion factor is applied to totals, rather than several separate factors applied to particular types of visitors with different registration rates, such as horseback riders and hikers, day-users and campers, and so on (Wenger and Gregersen 1964; Lucas and others 1971; Leatherberry and Lime 1981; Petersen 1985).

4. Wilderness permits. Permits are used where use is controlled; for example, camping in the backcountry of many major National Parks, all use of the Boundary Waters Canoe Area, and several wildernesses managed by the Forest Service in the southern Appalachians. Permits are also used in several wildernesses where use is unrestricted; for example, all National Forest wildernesses in California (only a few of which control use). Permits, in addition to their other uses, provide managers with recreational use data that are usually the most accurate of all use estimates. Sometimes adjustments are made for noncompliance and variation between planned and actual use (Lime and Lorence 1974; Kraushaar and others 1979; van Wagtendonk and Benedict 1980).

5. Trail traffic counters. Several kinds of automatic counters, such as pressure pads and infrared beam counters, are used to estimate numbers of visits (Leonard and others 1980), but estimates of visitor-days require other data on length of stay, either from trail registers or guesses, to multiply times visits.

Researchers' Use Estimation Techniques.—Researchers have used additional approaches that have been used infrequently by managers and also have studied the relation of actual use to data from trail registers and permits.

1. Direct observation. One such approach is personal observation as part of a formal systematic sampling plan. The sample is usually stratified by weekday/weekend, season, and perhaps access point or groups of accesses. This approach can produce estimates to any desired level of accuracy, but even for fairly modest accuracy, it usually requires considerable sampling intensity. Resulting high costs have limited usefulness of the method to managers (Lucas and others 1971; Leonard and others 1980).

2. Time-lapse photography. A movie camera is modified to expose one frame of film at a selected interval. The method has been used primarily to record river recreational use, and has been quite successful (Marnell 1977; Marnell and others 1978). This is because long stretches of rivers can often be photographed so that exposures evenly spaced at relatively long time intervals will not result in any parties going by unobserved. This is seldom the case on trails. There, exposure intervals close enough to record all visitors would exhaust film quickly, with most frames showing no visitors.

3. Cameras automatically triggered by traffic counters. A modified movie camera exposes a frame or two whenever a trail traffic counter, usually an infrared beam counter, is activated by passing visitors (or wildlife, including one grizzly bear on a Bob Marshall trail). The technology was developed originally by the Forest Service Equipment Development Center in Missoula, MT (DeLand 1976; Gasvoda 1978). It has been used in a number of research studies (Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Petersen 1985). Film is not used unneccessarily when no visitors are there, and persons classifying recreational traffic by viewing the film do not have to search through hundreds of frames to find those showing visitors. Automatic cameras can be used to directly record use or measure trail register registration rates, which is discussed further below. This method has been used mainly on trails, but can be used on fairly narrow streams, where the traffic counter's maximum range of 90 to 120 feet is not exceeded.

More information is obtained than from traffic counters alone. Method of travel—for example, hiking or horseback—can be determined and length of stay—day-use or camper—can usually be identified from presence or absence of large backpacks or pack horses. Direction of travel is obvious. Usually party size can be determined.

Equipment costs are significant for traffic counters, cameras, and film editors or special projectors (Leonard and others 1980), and care in installation is important. But a nearly complete record of use near an access point usually is produced at total costs well below personal observation, and without the boredom or hardships of enduring all sorts of weather that would afflict an employee sitting on a log hour after hour.

Concerns for privacy are critical. The usual guidelines suggested by agency attorneys are to: use the system only to measure and classify recreational visitor traffic, place the camera far enough from passing visitors or adjust the focus so that 8-mm photo quality is not good enough to identify individuals, and destroy the film after it has been viewed and traffic tallied (Leonard and others 1980). Apparently these guidelines have been observed reasonably well because controversy has been very limited.

This is an effective and reasonably cost-efficient system that has been adopted by many wilderness managers.

4. Formal systematic observation of visitor registration behavior. As early as 1961, researchers began studying visitors' responses to voluntary, unstaffed trail registers (Wenger 1964). The concept, still applicable today, was

that trail register data provide a base that could be adjusted by a mathematical operation to estimate total use if visitor registration rates were known.

Actual registration behavior was determined in several ways. Several early studies conducted brief interviews to collect the same type of information called for on the trail register, with interviews conducted far enough beyond the trail register to be out of sight of parties at the register and avoid influencing behavior (Wenger 1964; James and Schreuder 1971; Lucas and others 1971). Observation with binoculars was used in one study (Thorsell 1968). Pressure-plate traffic counters were tried (Lucas and others 1971; Leonard and others 1980), as were prototype ultrasonic traffic counters (Lucas and others 1971) and infrared beam traffic counters (James and Schreuder 1971). The most common technique in recent years, and the most effective, has been the movie camera triggered by an infrared beam trail traffic counter (Leonard and others 1980; Leatherberry and Lime 1981; Lucas and Kovalicky 1981; Lucas 1983; Petersen 1985).

A number of studies of registration behavior produced variable results (table 15). Overall registration rates in different wildernesses and other wild, roadless, backcountry areas, with various types of registration stations, ranged from a low of 18 percent in the Idaho Primitive Area, to a high of 89 percent in the Rawah Wilderness in Colorado.

The study results in table 15 suggest, at first glance, that registration rates have declined irregularly over the years. However, there may be little or no time effect. What probably accounts for most of this variation is the relative proportions of different types of use occurring in each study area. As table 15 shows clearly, there are large differences in registration rates among different types of visitors. Specific registration rates vary in response to local differences in registration stations and basic characteristics of user populations, but the pattern of relative registration rates is consistent to a degree that is rare in recreation research. Hikers always register at substantially higher rates than horse users. Campers always have higher registration rates than day-users. When method of travel and length of stay are considered in combination, camping hikers (backpackers) lead the list, followed by day hikers, and camping horse users; day horse users always have very low, often 0 percent, registration. The only test of self-issued mandatory permits (Lucas and Kovalicky 1981) had a slightly different order due to high registration by camping horse users. (Mandatory self-issued permits, used a few places primarily in the West, differ from trail registers in that they are mandatory rather than voluntary. A copy of the permit is supposed to be carried by the visitor for possible field checking, while another copy is deposited at the permit-issuing station.) Hunters, partly reflecting the travel-stay relationship, have low rates, much lower than nonhunters, and partially as a result, fall registration rates are lower than summer rates, with the one exception of the only study of self-issued permits (Lucas and Kovalicky 1981). Larger parties, at least up to moderately large groups, register at a higher rate than small parties, and single visitors have the lowest rate of all.

Table 15.—Reported percentage registration rates from studies of visitors' responses to trail registers

Wilderness area (State)	Year	Visitor types							
		All visitors	Hiker	Horse users	Day-use	Camper	Day hiker	Day horse users	Camping hiker
Three Sisters (OR), Mountain Lakes (OR)	1961-62	74	79	40	78	81	78	—	81
Mission Mountains (MT)	1968	65	66	44	63	74	—	—	—
Banff NP (AB)	1968	35	—	—	—	—	—	—	—
Rawah (CO)	1970	89	—	—	—	—	—	—	—
Selway-Bitterroot (ID & MT)	1974	28	31	11	19	49	—	—	—
Idaho Primitive Area (ID)	1975	18	—	—	—	—	—	—	—
	1976	35	—	—	—	—	—	—	—
	1977	23	—	—	—	—	—	—	—
Sawtooth (ID)	1975	78	—	33	—	—	85	—	87
Waterton Lakes NP (AB)	1976	78	78	64	—	—	—	—	—
Spanish Peaks (MT) (Spanish Creek, July-Aug. only)	1977	50	58	14	32	74	40	0	78
Spanish Peaks (MT) (self-issued mandatory permits)	1978	53	55	35	45	72	51	25	72
McCormick Forest (MI)	1978-79	66	[1]66	—	—	—	—	—	—
Bob Marshall (MT) (7 trails)	1981	20	39	7	18	20	24	0	47
Bob Marshall (MT)	1982								
Conventional trail register, at trailhead		32	34	8	21	54	23	0	57
Newly designed register, 1 to 3 miles up trail		69	80	50	55	74	65	14	88

[1]All visitors to the McCormick Forest were hikers.

Table 15.—(Con.)

Camping horse users	Summer	Fall	One-person parties	Small groups (2/2-3)	Medium groups (3-4/5-6)	Large groups (6-7 or more)	Weekday	Weekend	Source
			Visitor types						
—	—	—	37	73	82	84	72	76	Wenger and Gregersen 1964
—	74	41	55	63	72	66	72	62	Lucas and others 1971
—	—	—	—	—	—	—	—	—	Thorsell 1968
—	—	—	—	—	—	—	—	—	James and Schreuder 1972
—	—	—	10	35		17	30	26	Lucas 1975
—	—	—	—	—	—	—	—	—	Personal communications,
—	50	21	—	—	—	—	—	—	Dodds
—	35	15	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	—	Mullins 1975
—	—	—	—	—	—	—	—	—	Scotter 1981
50	—	—	—	—	—	—	—	—	Lucas (unpublished); Lucas and Kovalicky 1981
70	53	53	41	57		60	—	—	Lucas and Kovalicky 1981
—	72	57	60		84	100	—	—	Leatherberry and Lime 1981
7	35	5	—	—	—	—	—	—	Lucas 1983
									Petersen 1985
20	—	—	—	—	—	—	—	—	
56	—	—	—	—	—	—	—	—	

The areas where high registration rates have been reported are primarily backpacking wildernesses, with few horse users. These include Three Sisters, Mountain Lakes, Mission Mountains, Rawah, and Sawtooth Wildernesses, Waterton Lakes National Park, and McCormick Forest (table 15). The lowest overall registration rate for any of these areas was 65 percent. Areas with substantial horse and hunter use include the Selway-Bitterroot and Bob Marshall Wildernesses and the Idaho and Spanish Peaks Primitive Areas. At these areas, registration rates ranged from 18 to 50 percent, with most at the lower end. The only exceptions were the self-issued permit test in the Spanish Peaks (Lucas and Kovalicky 1981) (53 percent), and the experimental registration station tested by Petersen (1985) in the Bob Marshall (69 percent).

Locating trail registers some distance up a trail, rather than near the trailhead, appeared to result in higher registration rates in studies in the Sawtooth Wilderness (Mullins 1975) and the Spanish Peaks Primitive Area (Lucas and Kovalicky 1981). Petersen (1985) tested location in a controlled experiment. Two types of trail registration stations were moved from trailheads several miles up the trail and back on a random basis. Her results showed conclusively that up-trail locations produced substantially higher registration rates than trailhead locations. When the new station design was placed up the trail, registration rates more than doubled from rates at the old standard station at the trailhead.

Trail register messages also influence visitor registration behavior. Scotter (1981) and Lucas and others (1971) indicated that lack of understanding of the reasons for registration was a major reason for nonregistration. Petersen (1985) designed a sign (fig. 2) that presented three reasons very briefly, and visitors responded with higher registration rates. (The standard sign, which gave only a very general reason, read, "This will help us meet your needs in the area.") Camping horse users, in particular—usually a difficult group to get to register—more than doubled their registration rate.

Mathematical approaches to generating use estimates from trail register data suggest that simple procedures, regression or ratio estimation, work just as well as more complex techniques (James and Schreuder 1971, 1972; Lucas and others 1971).

5. Road traffic checks. This technique, sometimes called a "cordon line," involves gathering data on visitor traffic on access roads to a wilderness or similar area, through brief roadside interviews, and using these data as a base for estimates of total use and its characteristics. It is most practical for areas with only a limited number of access roads, especially roads that dead-end at the wilderness, and carry limited nonrecreational traffic. Sometimes road traffic counters have been used to aid in the expansion of interview data (Lucas 1964a). In other cases, traffic counters were not used, and interviews at roadblocks were used to estimate amount and type of use (Cushwa and others 1965). The technique is effective, but it is a major undertaking and costs can be substantial. This approach has not been used by managers.

Figure 2.—Experimental trail register design (from Petersen 1985).

Trend Analysis

Studies of trends in wilderness use and user characteristics have been scarce. Because of the problems described above with basic use data of low accuracy, lack of comparability between wilderness-managing agencies, and discontinuities over time, analyses of trends in amount of wilderness recreation use have been hampered.

Before passage of the Wilderness Act in 1964, the only established wilderness was in National Forests. The National Park Service and Fish and Wildlife Service had some lands designated as wilderness later, and the Bureau of Land Management much later after passage of the Federal Land Policy and Management Act in 1976. However, other than the Forest Service, none of the agencies have reported recreational use specifically for wilderness units. Thus, the data on use of National Forest wilderness are the main available record of recreational use and trends. Data began in 1946 and are available for every year thereafter, although units of measure changed from 1964 to 1965, and number of visits were not reported after 1969. Reported figures show some erratic ups and downs (table 16), and visits and man-days do not always parallel each other as one would expect unless lengths-of-stay were fluctuating sharply. The first years after the switch to 12-hour recreation visitor-days show curious changes. Average length of stay in 1966 was 3.4 12-hour days, but in 1967 the average dropped to 2.3. These shifts back and forth raise some concerns about accuracy, but, as the saying goes, "It's the only game in town." Taking the figures at face value, the rates of increase were highest in the 1940's and 1950's, with double-digit increases most years; slowed somewhat in the 1960's and 1970's, with single-digits most common; and decreases for several years. In the 1980's, decreases became more common than increases, despite additions to the wilderness system.

National Parks have reported overnight stays in backcountry, whether classified as wilderness or not, since 1971. Much of this use is essentially wilderness use, and most of it is in areas that may eventually become official wilderness. The trend for the major wilderness-type parks was steadily upward to a peak in 1976 (table 17). Since 1976, use has declined about one-third, and, except for a rebound in 1980, the downward trend has been steady.

Reasons for these declines are not clear. The trends for National Park and National Forest use (table 1) are rather different; since 1976, even the direction of change has been different in all but 2 years—1982 and 1983. If broad social-economic changes were causing decreased recreational use of wilderness-type lands, one would expect more parallel changes. Additions to National Forest wilderness could cause some differences in trends, but most of the areas were added in 1984 and are not reflected in the data in table 1. Large Alaskan areas were added in 1980, but their use was light, only 3 to 4 percent of all National Forest wilderness use most years.

McCool (1985) examined the hypothesis that wilderness designation causes a spurt in recreational use, "a kiss of death" of sorts. He had use data for years before the Rattlesnake Wilderness, MT, was designated—the only case where such data existed—as well as after designation. He found little change, and concluded that the designation effect is not inevitable.

Petersen (1981) approached the designation effect by tracing rates of change in reported use for newly designated National Forest wildernesses to determine if new areas showed more rapid increases than long-established areas. Most did, but the effects were variable and not as large as common speculation would have suggested. Studies of trends in use and user characteristics are almost as scarce, and most include only a few characteristics and rather short time periods.

Changes in numbers of visitors for the main types of use in the Boundary Waters Canoe Area from 1961 to 1966 were studied by Lucas (1967). Total use increased 19 percent, but paddling canoeists and boat campers both increased about 55 percent. Use in 1966 was more evenly distributed among access points than in 1961. More visitors came from outside Minnesota, parties became slightly larger, and stays became shorter over the 5 years.

Use of the Allagash River, ME, more than doubled from 1966 to 1975, parties became smaller, and stays shorter (Cieslinski 1980). Visitor surveys in 1973 and 1975 included data on only eight variables, with little change except a decline in the number of large parties.

Use of the Rattlesnake Wilderness grew slightly from 1977 to 1981, and groups grew smaller (Corti and others 1982). Limited visitor surveys in 1978 and 1981 showed few changes, except a tendency for 1981 visitors to have less previous experience in the area than 1978 visitors.

Table 16.—Reported annual total use of National Forest wilderness and primitive areas, in thousands, and percent change between years

	Man-days		Visits		Recreation visitor days	
Year[1]	Thousands	Percent change	Thousands	Percent change	Thousands	Percent change
1946	406	—	144			
1947	499	+23	194	+35		
1948	657	+32	213	+10		
1949	761	+16	244	+15		
1950	787	+3	246	+8		
1951	809	+15	312	+27		
1952	953	+18	387	+24		
1953	1,317	+38	408	+5		
1954	1,047	−21	396	−3		
1955	1,175	+12	462	+17		
1956	1,364	+16	448	−3		
1957	1,654	+21	535	+19		
1958	1,685	+2	556	+4		
1959	1,950	+16	562	+1		
1960	1,903	−2	614	+9		
1961	2,047	+8	757	+23		
1962	2,136	+4	815	+8		
1963	2,752	+29	937	+15		
1964	2,872	+4	957	+2		
1965			NA	—	4,522	—
1966			1,392	[2]+45	4,791	+6
1967			2,029	+46	4,690	−2
1968			2,028	0	5,056	+8
1969			[3]2,028	0	5,072	0
1970					5,843	+15
1971					6,691	+15
1972					6,459	−3
1973					6,682	+3
1974					6,743	+1
1975					7,513	+11
1976					7,106	−5
1977					8,008	+13
1978					8,620	+8
1979					9,605	+11
1980					9,268	−4
1981					11,417	+23
1982					11,158	−2
1983					9,909	−11
1984					10,209	+3

[1]Years are calendar years through 1976 and fiscal years (October through September) thereafter.
[2]Percent change for a 2-year period.
[3]Reported visit totals for 1968 and 1969 were identical; this is not an error.

Use of Yosemite National Park's backcountry rose rapidly to 1975, but declined from then to 1979 (van Wagtendonk 1981). (Park Service annual use reports show backcountry camping has since risen and declined again.) Two separate surveys only 2 years apart (1973 and 1975-76) showed little change in age, education, income, party size, and length of stay. There were more female visitors in the latter survey, and use was a little more evenly distributed over the season and over the trail system.

In 1970 and 1982, comprehensive visitor surveys were carried out in the Bob Marshall Wilderness complex, which includes the Bob Marshall, Great Bear, and Scapegoat Wildernesses in Montana (Lucas 1985b). The major change in use characteristics was a shift from predominantly horse use in 1970 to mainly backpacker use in 1982. Both horse and hiker use increased, but hiker use grew much faster. Many other changes seemed to stem from this basic shift: shorter stays, smaller parties, a smaller proportion of visits with outfitters, some shift in activities from more consumptive to more contemplative, more summer and less fall use, and less dependence on wood fires. Other changes in use characteristics were: less weekend peaking and less concentrated use. These changes seemed to imply lower potential for impacts to resources on a per-party basis.

Most visitor characteristics remained about the same or changed only moderately from 1970 to 1982. The essentially unchanged characteristics included urban/rural residence, type of social group, age distribution, high levels of overall wilderness experience, and club membership. Modest changes from 1970 to 1982 included more visitors

Table 17.—Reported total annual use of wilderness and backcountry in 17 major National Parks[1]

Year	Overnight stays Thousands	Percent change
1971	712	
1972	857	+20
1973	910	+6
1974	1,027	+13
1975	1,115	+9
1976	1,231	+10
1977	1,098	−11
1978	904	−18
1979	902	0
1980	996	+10
1981	968	−3
1982	881	−9
1983	865	−2
1984	833	−3

[1]Includes data from Big Bend, Denali (Mt. McKinley), Everglades, Glacier, Grand Canyon, Grand Teton, Great Smoky Mountains, Kings Canyon, Mount Rainier, North Cascades, Olympic, Rocky Mountain, Sequoia, Shenandoah, Voyageurs, Yellowstone, and Yosemite National Parks.

from out of State, more women, higher educational levels, more visitors in professional and technical occupations, and less previous experience in the Bob Marshall Wilderness complex, especially for backpackers. These changes also reflect the shift to more backpacker use. Many changes in visitor characteristics seem to point to slower future growth in use.

Burde and Curran (1986) studied changes in use, users, and attitudes in Great Smoky Mountains National Park's backcountry from 1973 to 1983. Visitors in 1983 were older, more experienced, more often with peer groups of friends than family groups, and in smaller groups. Slightly more women visited the backcountry in 1983, and average trip length was about the same across the two study periods.

Projections

Projections of wilderness recreational use have been limited by poor and noncomparable basic use data, and also by scanty knowledge of the relationship of wilderness use to causal factors.

Probably the earliest projection of wilderness use was made as part of the Forest Service National Forest Recreation Survey project in 1961 (USDA-FS 1961). An unpublished projection of National Forest wilderness use foresaw a tripling of man-days by 1976 and more than eightfold growth by the year 2000 (table 18). This is a little more than a 5 percent average annual rate of increase. The actual reported figure for 1976 was 7,105,600 12-hour visitor-days, compared to 5,804,000 man-days—a different unit of measure. There is no way to convert from one unit to the other with any precision because fractional man-days had highly variable definitions in visitor hours, but a suggested rule of thumb is 1.5 visitor-days per man-

Table 18.—National Forest wilderness use projections in thousands of man-days and percentage change projected

	1959 (actual)	1976	Percent change	2000	Percent change
National Forest Recreation Survey (1961)	[1]1,950	5,804	+198	16,183	+730
Outdoor Recreation Resources Review Commission (1962)	[1]1,399	4,948	+254	12,053	+762

[1]The National Forest Recreation Survey included data for all areas; the ORRRC study excluded areas smaller than 100,000, then called "Wild Areas."

day (Hendee and others 1978, p. 289). Using 1.5 as a rough conversion factor suggests projected 1976 use of about 8,700,000 visitor-days, or about 22 percent more than was actually reported.

The projection technique was based on simple assumptions, with no supporting research (there was no recreation research to speak of in 1959). Per capita use was projected by multiplying the ratio of projected per capita real income in the target year to its level in the base year times similar ratios for leisure and miles traveled. The result was multiplied by projected population. This procedure illustrates another problem in recreation projections; the procedure requires projections of population, income, leisure, and travel, variables that are probably as hard to project as recreation use itself. The "independent variables" also are obviously not independent of one another.

At almost the same time, wilderness use was projected as part of the Outdoor Recreation Resources Review Commission (ORRRC 1962) studies. They also worked only with National Forest data (no wildernesses were managed by any other agency before 1964), and also used man-days. These projected rates of increase were similar to those of the Forest Service study (USDA-FS 1961) (table 16). This is surprising because the projection procedures were quite different. The ORRRC projections were based only on income and population. Per capita wilderness use was related to income with a regression model, using National Forest-reported wilderness and primitive area man-days from 1947 to 1959. These predictions of per capita use were multiplied by projected population.

There appears to have been almost a 20-year gap before other wilderness use projections were developed in response to Resource Planning Act (RPA) requirements. Three projection studies were published in 1982 or 1983, all of them using more advanced statistical techniques than the early studies. Jungst and Countryman (1982) developed several models. One approach used time-series cross-sectional regression, with both supply and demand variables, with a resulting projected average annual rate of increase of 2.6 percent to the year 2020. The second approach used regression analysis, using supply, population, and lagged wilderness use (use in the previous year) as independent variables. This model projected an average annual rate of increase of 7.2 percent to the year 2020.

Hof and Kaiser (1983a, 1983b) did not project wilderness use itself, but included several activities that probably parallel wilderness use, particularly dispersed primitive camping. Their approach involved estimating per capita participation using a number of socioeconomic and supply variables in a regression model, and applying the equation using high, medium, and low projected values for the independent variables. Primitive camping was projected to increase from a 1977 base of 100 to 155, 205, or 311 by 2030 in the low, medium, and high scenarios. These indices translate to annual average rates of growth of less than 1 percent to a little over 2 percent.

A very different sort of time frame was used by Oliveira and others (1983) to project wilderness use a few days into the future (by projecting arrivals and departures). This was intended to determine available unused capacity for which permits could be issued in areas with use control programs.

It is clear that knowledge of wilderness use projections is very limited. About all the handful of studies agree on is an increase in future use, but at widely varying rates. None suggest the slowing or declines that have appeared in recent years.

ADOPTION OF RESEARCH BY MANAGERS

Successes

Many wilderness management plans for areas where use and users have been studied have applied these research data. Estimates of the amount and type of use have been used to evaluate "people pressure" and determine the need to modify or limit use. The same types of data have been used to decide on the need for developments, such as horse loading ramps or outhouses, at specific trailheads. Trail plans have used data on use distribution to set appropriate maintenance standards, evaluate possible changes in the trail network, and judge the potential for conflict between different types of use. Plans for areas that have not been studied have also been affected in general ways by improved knowledge of the typical characteristics of use and users.

The Limits of Acceptable Change (LAC) system has been developed to manage wilderness recreational carrying capacity (Stankey and others 1985; Lucas 1986). In the initial application of the LAC system to the Bob Marshall Wilderness complex in Montana, use pattern data were used to help define wilderness opportunity zones. Use data were applied in a similar way in the Maroon Bells-Snowmass Wilderness in Colorado. Use data were also employed as input to wilderness use simulation models to help establish encounter standards and select locations for monitoring encounters in the Maroon Bells-Snowmass Wilderness and the Desolation Wilderness (Shechter and Lucas 1978).

Information on amount of use and use distribution has generally shown that even the most heavily used wildernesses are lightly used during many times and in many places. Managers in some areas, such as Linville Gorge, have responded to this information by dropping overall area use limits, and instead have adopted weekend limits at high use times and an informational program to teach low-impact behavior.

Efforts in some areas to disperse or redistribute use have applied data showing existing uneven, concentrated use patterns to try to redistribute use and plan specific efforts. Sometimes the data on use patterns have been directly provided to visitors (Lime and Lucas 1977; Lucas 1981; Roggenbuck and Berrier 1982). Use pattern data have been applied to deciding when and where to station persons to make educational contacts. Data on visitors' home locations and membership in conservation and outdoor clubs have been used to choose target areas and audiences for education efforts. Finally, the high education levels of wilderness users have encouraged managers to turn to informational contacts to teach minimum-impact use practices.

Some regulations have drawn partly on use/user data. Limits on party size are the main example. Limits have been justified mainly from studies of social and ecological impact; and in the early 1970's some areas established limits at 12 to 15 persons per group. Use data have since shown that there are relatively few parties of this size, so relatively few users are affected. More recently, such party size regulations have not been adopted, not because large groups are now condoned, but because the restrictions are no longer necessary; there have been reductions in the size of visitor groups.

Basic use and user data have been essential for the relatively few trend and projection studies, which are potentially useful to management.

The basic trail register system, widely used, especially by the Forest Service, was developed by research (Wenger 1964).

Missed Opportunities

In general, available research results of use and user characteristics have been applied well by policymakers and managers. There are some cases, however, where application has lagged. Most notable among these are wilderness use estimation technology, implications of the large number of day-users of wilderness, access and trail routing, wilderness travel simulation technology, comprehensive application of information and education programs, and a comprehensive financial support program for professional wilderness management.

Although the development of wilderness use estimation methods has not been completed, available knowledge is not being used fully. Research has shown that location of trail use registration stations some distance up the trail produces much better response from visitors (Lucas and Kovalicky 1981; Petersen 1985), but trailhead locations continue to predominate, mainly because of convenience and associated lower costs. The necessity of determining registration rates to estimate use is obvious, but it seldom is actually done by managers. Cost is the major hindrance, although photographic monitoring equipment, which research helped develop, reduces costs considerably.

One of the most surprising and pervasive findings of use and user research is the large number of day-users in wilderness. These individuals seldom penetrate to the wilderness core and likely have relatively light ecological

impacts. They do, however, cause congestion along the periphery and outer zones of wildernesses, and they may be neither seeking nor receiving wilderness-dependent experiences. If this is the case, managers might reduce wilderness impacts by developing additional day-hiking opportunities in areas outside wilderness and informing hikers of these opportunities. In some cases such opportunities already exist, and all that is needed is a better information system. Some managers, such as in Shining Rock Wilderness in North Carolina, have already adopted such a strategy, but the potential for more extensive use exists.

The distribution of use among access points and along trails is very uneven in many areas. At the same time, use is largely confined to trails. Access points and trail routes thus become powerful management tools. By altering trail system configuration (such as closing some trails, adding loop trails, or branching trails from major trail trunks) and improving or failing to maintain access routes, managers can largely influence how many people use various zones of wilderness. Again, this strategy has been used by management, but not as extensively as it might be.

As has already been noted, many wilderness managers, such as those in Eagle Cap Wilderness, OR, and Shining Rock Wilderness, NC, have recognized the high education levels of wilderness users and have implemented informational programs to disperse use or teach low-impact practices. However, few areas, even the Boundary Waters Canoe Area or Yellowstone National Park where successful pilot programs to redistribute use through information have been tested (Lime and Lucas 1977; Krumpe and Brown 1982), have continued these programs. Research suggests that success of such programs depends on the source of the information, amount of information given, the timing of message transfer, the channel used to communicate the information, actually getting the message to the target audience, and characteristics of the audience and the situation (Roggenbuck and Watson 1986). Available knowledge of such wilderness use and user characteristics as education levels, use patterns, activities, behavior, background experience, and knowledge could be used to better tailor messages to audiences. This tailoring process admittedly must be subtle, perhaps as much art as science.

Limited budgets are almost certainly the most frequent reason for any lags in the adoption of management programs suggested by use and user data. Developing a soundly funded program to manage wilderness is probably the biggest challenge of the next decade. A partial solution to the dilemma may be found in data on wilderness user characteristics. Wilderness users as a group have above-average incomes. Most could afford a modest wilderness use fee.

RESEARCH ISSUES AND FUTURE DIRECTIONS

Use Measurement Technology

It is apparent that many types of wilderness research are hampered by the poor quality of recreation use estimates. Projection and trend studies suffer severely, as has been pointed out, but so does research on impacts to the environment. Poor use data hinder skillful, professional management as well. Thus, we conclude that development of improved use measurement technology is still an important need.

Accurate techniques are available; the problem is lack of a cost-effective, accurate technique. Years ago, the scientists who did the most research on this topic (James and Schreuder 1971) said, "The authors believe that a satisfactory procedure is near at hand." That statement was probably true then and, unfortunately, it is still true almost 15 years later. The concerted research effort to close the gap never occurred.

Wilderness use measurement technology is not easy to develop, or it would have been done before now. However, it is a relatively "solvable" problem. If adequate resources were devoted to it for a reasonable time period, perhaps 5 years or so, the probability of solution would be high, probably higher than for almost any other significant problem (Shafer and Lucas 1979).

Coverage of Use/User Studies

Visitor surveys have been the most common approach to studies of wilderness use and users. They have become less common in recent years. We welcome the emphasis on research on relationships and processes, but there is also a need for careful descriptive research. The results are directly useful to managers and planners, and also help researchers in selecting appropriate study areas, designing sampling plans, and extending results to other similar situations. Repeat descriptions can yield cross-sectional trend analyses.

We feel that more site-specific comprehensive visitor surveys are needed. The National River Recreation Survey (Knopf and Lime 1984) could be a model. Standardized instruments are used on a wide variety of rivers, distributed fairly evenly across the country and managing agencies, with rigorous sampling plans.

Wilderness use and users are almost undescribed in some regions of the country—the Southwest, for example—and they have been described in only a few wildernesses in many areas, including California, which has more reported wilderness use than any other State. Except for the Boundary Waters Canoe Area Wilderness, wildernesses in the Midwest and South-Central regions are unstudied.

Some types of use have been little studied anywhere. Most wilderness surveys have concentrated on the main summer use season. Hunters and other fall visitors have been included in only a few studies, and none have focused on them. Winter snow-season use has been little studied. (The only winter use studies we found are by Gilbert [1980], Taylor and Mackoy [1980], Taylor and Spencer [1980], and Hammitt and Hughes [1984].)

Data for many areas that have been studied are over 20 years old. In the meantime, use has more than doubled, the environmental movement arose and peaked, and a new generation of people has become wilderness visitors. The validity for the mid-1980's of visitor profiles from surveys done in the 1960's is a major question.

Trends

More knowledge of trends in wilderness use and users is imperative for effective management. In fact, one of the main uses for improved recreational use measurement is identification of trends.

Similarly, user surveys, although useful in their own right, become much more valuable when trend information from repeat surveys or other sources is available to aid in interpretation. Managers can better evaluate a potential problem situation if, in addition to information on the current situation, they know if the particular case is improving, deteriorating, or stable. If groups are becoming smaller, for example, as they seem to be in many places, the need to institute party size limits is reduced. If visitors' reports of campsite solitude show fewer contacts with other campers, the need for additional actions by managers is far less than if the trend is toward higher contact levels, even though the current level of contacts is identical in both cases.

Stable or declining use suggests a need to reexamine some use controls. Most controls were instituted in a time of rapid growth and anticipated future growth. Managers were often trying to nip problems in the bud as much or more than solving existing problems. Some use rationing, and assigning of campsites, might be relaxed if use is dropping. For example, some National Parks with stringent visitor controls now report only half as much use as 8 or 10 years ago.

In addition to multiple cross-sectional survey data, other longitudinal approaches are needed. Following the changes in wilderness user behavior and experiences (and responses, attitudes, and preferences) of a sample of individuals over time, in a panel study, would tell us things about the dynamics of change that are only hinted at in multiple cross-section surveys. In particular, succession-displacement can only be studied with longitudinal research designs. This approach, effectively used by LaPage and Ragain (1971) in research on developed camping, can enrich our understanding of the processes of change. This approach would be especially useful for understanding the recent declines in use, and might suggest if the future is likely to feature declines, stability, or renewed growth.

Privacy, Consideration

Concern for the subjects of visitor research must be kept high. Wilderness visitors have been marvelously cooperative with researchers. They answer questions with sincerity and friendliness, and exceptions are so rare as to be notable. In 25 years of wilderness visitor research, one of us (Lucas) has encountered only two visitors who declined to provide information, and one of them was almost surely an unlicensed, illegal outfitter who, understandably, wanted to keep a low profile.

Further evidence of the good will of wilderness visitors is the extremely high rates of return of mail questionnaires, generally in the 80-percent and even 90-percent range. Wilderness visitors truly must be one of the very best special populations for social science research.

Beyond legal questions, particularly for photographic observation techniques, researchers owe these visitors all the consideration and sensitivity possible. Imposing on visitors' good will and interfering with an experience that is very important to most of them must be minimized. For example, interviews at campsites interrupt visitors (although researchers who have used this technique report they sensed little resentment) (Roberts this volume), and only a few types of studies with objectives that require data on visitor evaluations of specific, onsite conditions are appropriately approached onsite. Guarantees of confidentiality and anonymity must be strictly observed. Overstated promises are unethical.

Cameras used for observation are a powerful new tool with the potential for abuse. Their use must meticulously follow legal guidelines, but also be sensitive to people's concerns. A trail register is essentially a public place; a campsite or a wilderness swimming hole is not, and photographic observation should be limited to public places. It seems like a desirable courtesy to attach a small, simple sign to cameras and trail traffic counters explaining briefly what they are and what their purpose is, and including a phone number. This would ease curiosity or puzzlement by the few visitors who do detect equipment. Leatherberry and Lime (1981) did this, as did Petersen in her 1985 study.

Sampling Approaches

Visitor studies must be based on rigorous, scientifically valid sampling systems. Convenience samples, with undefined probabilities for sampling elements (individuals or groups), undefined populations, and unspecified sampling frames are not justified now, if they ever were. Enough is known about the difficult sampling situation to design valid approaches. Costs may be higher and, as a result, samples may be smaller, but, in social science, a large sample never can compensate for poor sample quality. Most field samples are cluster samples, and this needs to be recognized. Pretending a cluster sample is a simple random sample is common, but it almost always results in overestimates of the precision of estimates—in other words, calculated confidence intervals are misleadingly narrow.

Restrictions on Survey Research

Asking people for information about their use of wilderness and about themselves needs to be done with care. As discussed above, most wilderness visitors are very cooperative and welcome the chance to tell researchers about something that is near and dear to their hearts. However, asking poorly worded questions, gathering data not related to important study objectives, or gathering information with an inadequate sampling plan can result in a waste of respondents' time and effort. Very poor questions can even be embarrassing.

Therefore, review and control procedures are justified. Universities have committees for the protection of human subjects that review and approve proposed studies in social science, psychology, and medicine. Researchers who are Federal employees, or who are supported by Federal agencies, must obtain approval from the Office of Management and Budget (OMB) for any collection of information

from 10 or more people. This requirement began with the Federal Reports Act back in the 1940's, and was made more stringent in the 1980 Paperwork Reduction Act. The major concern motivating the legislation was the heavy burden imposed on businesses and local governments to provide information for regulatory and taxation purposes or to qualify for some benefit such as cost-sharing. Horror stories abound of several agencies independently asking for similar information, one this month, another next month, but in sufficiently different ways that the same answers could not be used for all of the forms. Claims were common that information was requested that the agency did not really need or use. Companies claimed they had to hire extra accountants to fill out complex forms, which they were almost always legally required to do.

It is a long step from legally required business forms affecting numerous firms to small-scale, voluntary surveys of wilderness visitors. The common OMB term "respondent burden" hardly seems applicable to the wilderness visitors who are almost always willing and often eager to answer questions.

The problem is not the need for a review and approval process. We agree this is necessary for quality control to protect the public, the taxpayers, and also responsible, qualified scientists from poorly done survey research. The difficulty is the time required and the uncertainty of the process. To obtain approval, study planning now needs to start about 18 months before fieldwork is to begin. Scientists should submit the questionnaire, study plan, and extensive, detailed question-by-question justification at least 6 months before data gathering is planned to start. This submission is handicapped, how severely is unclear, if the study has not previously been included in the annual "Information Collection Budget," which requires preplanning almost a year before actually seeking OMB approval, and thus results in the total lead time of about 18 months cited above. Approval generally is perceived as a somewhat chancy "win some-lose some" proposition, although scientists have usually eventually received approval.

The effects of this slow, cumbersome approach are several: (1) a lot of work for someone at OMB, with little significant public benefit; (2) inability of researchers to respond quickly to emerging problems, managers' concerns, new scientific concepts, or follow up promptly on results of earlier studies; and (3) less chance for the public to express its desires and concerns. No other type of natural resource research must face delays such as those imposed by this formidable barrier. The result is that less wilderness visitor research is done. Some studies have been designed to use research techniques other than questionnaires to avoid the lengthy struggle, even though the study might have been strengthened if survey research methods had been included. We suspect some problems have been chosen for research because they could be studied without needing OMB approval for questionnaires.

Wilderness managers who might want to monitor key elements of visitor use to implement plans, judge their effectiveness, and guide their modification are stymied if they follow the law strictly. Monitoring levels of solitude, visitor conflicts, or visitor evaluations of changing recreational impacts has generally required specific approval for time and place of use of questionnaires, and busy managers have not had the time and energy to seek approval for monitoring that could not begin until the next year or, more likely, the year after next. Without systematic monitoring, they must make do with hunches and impressions. There are too few researchers to be able to do the monitoring for them (and researchers have other duties), and many managers have felt unable to do the monitoring themselves.

It would seem to be in everyone's interest (OMB officials, researchers, wilderness managers, the public, and taxpayers) if a simpler, quicker review process could be developed. One possibility might be limited delegation of authority from OMB to Federal agencies doing wilderness visitor research. In the Forest Service research branch, for example, the typical recreation and wilderness research scientist has a Ph.D. with social science training and 15 to 20 years of experience in research. Perhaps several of these scientists could be assigned the duty of serving as a peer review board for studies proposed by Forest Service scientists and their university cooperators.

This would require OMB delegation, which could be limited to voluntary interviews or questionnaires involving less than 1,000 respondents. Similar limited approval for wilderness monitoring by managers could be arranged. The risks from such an arrangement seem minimal and the potential benefits great.

Household Survey Need

Most research on wilderness use and users has been carried out onsite, with current visitors to a particular wilderness. Very few studies have involved the general public, or household studies. One reason is that, for all the difficulties of onsite sampling, general population studies focused on wilderness use are probably even more difficult, because wilderness users are a minority in most populations.

Nevertheless, many types of important questions cannot be answered just by onsite studies. Former visitors who have stopped coming to an area will be omitted, of course, and their reasons will remain unknown. Changing health, declining interest, or dissatisfaction with area conditions or with management actions may be involved, but we will never know if we rely on onsite surveys. This seems critical to explaining the surprising recent declines in use. What substitutes, if any, former visitors have found will not be known, either. Some of these questions could be addressed with longitudinal studies as well as general population surveys.

Similarly, potential visitors and the reasons that have kept them from becoming active visitors cannot be studied onsite, nor with longitudinal studies. Only general population surveys will reach this subpopulation. Other subjects, such as wilderness values and benefits to nonvisitors, can also only be studied in this way.

User Knowledge Research

There is a great need for wilderness use and user research to focus on visitors' knowledge of low-impact wilderness practices. Agreement must be reached through empirical research on what the ideal minimum-impact

behaviors are. For example, some wilderness areas now recommend use dispersal to minimize impacts; others recommend use concentration. Some leave all firerings, some destroy most but leave one at each campsite, and some destroy all. Different methods are recommended to adequately dispose of human wastes. Once acceptable practices are selected, procedures must be developed to teach and measure knowledge of these practices. More information is needed on the relationship between knowledge of low-impact practices and actual behavior in wilderness. Finally, high-impact wilderness user groups must be identified, and reasons for their impacting behavior determined. We need to know if their impacts can be reduced through educational efforts, or if their impacts are the inevitable result of intrinsic use and user characteristics.

SUMMARY OF WILDERNESS USE AND USER RESEARCH

Any summary of wilderness use and users, trends, and projections must be prefaced by an acknowledgment of the lack of sufficient and system-wide research. Most wilderness use and user research has occurred in the Rockies and the Boundary Waters Canoe Area, with limited additional work in California, New England, and the Southeast. The Southwest, the Deep South, the Midwest except for the Boundary Waters Canoe Area, and even California have been little studied. In addition, most research has been conducted in mountainous and alpine wildernesses. As the Wilderness System has become more diversified to include a range of ecosystems, there is a need to study wilderness use and users in desert, swamp, and coastal plain wildernesses. Also, past research on use and users has focused primarily on National Forest wilderness, with limited coverage of National Park areas. There have been virtually no published studies on Fish and Wildlife Service and Bureau of Land Management-managed wilderness. Most research has only covered the summer and sometimes the fall season. We know little about spring and winter users, except that winter use is reported to be rising in many places. There is a critical need for more research because limited work suggests that wilderness use and users may differ more across seasons of the year than across time, areas, or regions (Hughes 1985). Finally, there have been almost no followup studies of the same areas across years. Such longitudinal studies are needed to determine trends and projections and understand causal factors.

While acknowledging that additional research to reduce knowledge gaps may provide more insights, we are struck by the similarities of wilderness use and especially users across areas, regions, and even year of study. Similarities are much more pronounced than differences. Indeed, the profile of wilderness users is much clearer than it is for other recreationists (Hendee and others 1978).

User Characteristics

There is a moderate overrepresentation of young adults among wilderness users. Under-35-year-olds are the most common. However, the 36-45 age group is also overrepresented in most areas, and both children and older adults visit wilderness in substantial numbers. Limited research suggests that the age structure of users is not changing through time.

Males are the big majority among wilderness users, usually from 65 to 85 percent of all visitors. Horse users are more typically male; hikers somewhat more likely to be female. Trends suggest an increasing use of wilderness by females. Wilderness is certainly not the absolute domain of men.

The most distinguishing feature of wilderness users is their high education. Everywhere wilderness users have much higher education than the general population for the States where they reside. For most areas, the percentage of wilderness users who have attended or are attending graduate school is larger than the percentage of the U.S. population that goes to college. Recent studies also show that education levels of wilderness visitors are even higher now than in the past.

Apparently there is more variation in the occupations of wilderness users across areas than for most other user characteristics. Generally, most users are professional and technical workers, followed by students. Housewives and clerical, sales, and service workers are the most underrepresented. Exceptions to this profile are large, western, horse-oriented wildernesses and scattered areas where local, rural users are common. Farmers, ranchers, and blue collar workers are more prevalent in these areas. Still, the typical user is a professional, and trends suggest that this will be even more the case in the future.

As a group, wilderness users have somewhat above-average incomes. For most areas, however, wilderness visitors could not be classified as wealthy. Most eastern area and California users have incomes well above the national average, but they appear to reflect the generally higher incomes of the residents of these States. The users of a few areas with considerable horse and outfitting use or airplane access apparently do have unusually high incomes. Research indicates that high incomes are not needed to enjoy most wildernesses. The typical visitor resides near the wilderness area, and costs per day to use and enjoy wildernesses are low.

Typically most wilderness users reside in the State where the area is located, and indeed most come from the region of the State that includes the wilderness. Thus, from the standpoint of recreation, most areas have a local or regional clientele. Wilderness areas in the East appear to diverge somewhat from this tendency. There, more visitors are from out of State. This likely reflects the small size of many eastern States, the scarcity of wilderness resources, and the high demand for wilderness experiences.

Most wilderness visitors are urban, but so, too, is the U.S. population. In many areas the proportion of urban to rural visitors is about equal to the proportion found in the State where the wilderness is located. This suggests that the overrepresentation of urbanites in wilderness may not be as great as some have suggested. In many areas the urban users had a predominantly rural upbringing, but this tendency was less strong among eastern area users. The proportion of urban to rural residents within wilderness appears quite stable for those few areas that have been studied in both the 1970's and 1980's.

Membership in wilderness, conservation, and outdoor clubs is generally low among wilderness users, usually below 35 percent. Exceptions appear to be some eastern areas with a highly urban clientele. Different kinds of users often belong to different types of organizations. Hunters and horse users more often join local clubs such as rod and gun clubs, while hikers have a tendency to belong to larger national conservation organizations.

Most wilderness users have considerable previous experience in wilderness. For most areas, 60 to 90 percent of the users have previously been to wilderness or backcountry areas, and about half have been to the study area before. Limited evidence suggests that visitors to recently established areas have less previous experience in the area. This suggests that wilderness designation does attract new clientele. Also, most wilderness users make multiple visits to wildernesses each year.

The most common group type in wilderness is the family—either the family alone or the family with friends. Such groups generally make up the majority of all groups, and limited research suggests their numbers are increasing. Groups of friends are typically the second most numerous. Organized groups such as Scouts or church groups usually comprise fewer than 10 percent of all parties.

Use Patterns

Distribution of wilderness use is very uneven through time, across areas, and within areas. Weekend peaking of use is severe, especially in western wilderness areas close to population centers. Peaking seems even more prevalent among winter wilderness users. On the other hand, the weekly pattern of use seems more evenly distributed among eastern areas, and recent studies show less weekend peaking than did earlier research.

Summer is the high season of use most places, but the ratio of summer to off-season use varies a great deal by area. Some areas have peaks of use of short duration during the fall hunting season, and October is a high-use month because of fall color in some eastern areas. Spring is a high-use time in a few low-elevation areas in the Southwest and southern California. Finally, while winter is typically a very low use period, use during this time appears to be increasing.

Use is also extremely variable among the many areas of the Wilderness System. A few areas often account for a third or more of an entire agency's wilderness visitation. Those near major population centers, such as, those in the southern Appalachians, New England, Minnesota, and California, are typically the most heavily used, but location does not explain all the variation. Some swampy wildernesses in the Southeast are lightly used, and several of the recently established eastern areas have little use. Such absence of use may be due to the lack of special attractions, absence of trail or travel routes, or lack of knowledge of the areas.

Use is also concentrated at a few entry points almost everywhere. Typically about a third of an area's trailheads account for about 80 percent of all use. Winter use appears even more concentrated, but summer use of eastern areas appears somewhat less concentrated. Some evidence suggests that dispersal of summer use to more trailheads is currently taking place. Cross-country travel—travel for considerable distances off trails—is low everywhere, but lower in the Northern Rockies than in mountain areas in California. Use of trails within areas is highly variable, and appears to be affected by trailhead location relative to population centers, ease of road access to the trailhead, trail system configuration, distance from the trailhead to the wilderness, and location of area attractions. Campsites tend to be located near water, and while campsite use is very uneven, it tends to be less so than use of trail segments.

Party size is small, averaging about four individuals in National Forest areas and two to three persons in National Park areas. Lone individuals are rare everywhere, but are about twice as common in National Park backcountry (10 to 15 percent of all groups) as in National Forest wilderness (where they typically make up from 5 to 10 percent). Parties of 10 or more accounted for 5 to 10 percent of use almost everywhere. Also, group size appears to be getting smaller through time.

Hiking is the primary method of travel everywhere except for such water areas as the Boundary Waters Canoe Area and for a few horse-oriented areas such as the Bob Marshall. There is almost no horse use in eastern wilderness areas; and even in western areas, the trend is away from horse use and toward backpacking use. Indeed, the biggest change that Lucas (1985b) found between the 1970 and 1982 use patterns among three western wilderness areas was a shift in proportions of total use away from horse use and toward hiking.

Correlated with the decline in the proportion of wilderness visitors who use horses is the general decline in the proportion of visitors who employ outfitters. Most areas studied have less than 1 percent of their visits outfitted. Only the Bob Marshall and the Great Bear Wildernesses have sizable numbers of outfitted parties, but the Bob Marshall Wilderness complex dropped from 35 percent outfitted groups to 17 percent from 1970 to 1982. Outfitting levels are quite high on some wilderness whitewater rivers, and also for a few large western wildernesses during the fall hunting season.

Length of stay of wilderness trips is short and getting shorter. Most areas have average lengths of stay of about 2 to 3 days. Exceptions are longer trips in the BWCA, the Bob Marshall, the Great Bear, and summer users in the backcountry of the Great Smoky Mountains National Park. In some areas 50 percent of all use is day-use, but this is highly variable. Trips of a week or more are rare everywhere, and distance traveled in wilderness is typically short. Horse trips tend to be longer than hiking trips. Winter use is generally shorter in time and distance than summer use, and length of stay is highly variable among eastern areas.

Finally, most wilderness users engage in multiple activities in wilderness. Generally, hiking, fishing, and photography are the most frequent activities. Following these in importance are nature study and swimming. Certain wilderness activity packages are common to different wilderness areas. The most common activity package includes hiking, fishing, swimming, and nature study, but low hunting and horse use. Desolation Wilderness is a

prototype of this wilderness type. At the other extreme are areas such as the Bob Marshall and the Great Bear that have high horse use, hunting, and photography, but low hiking, nature study, and swimming. Limited trend data suggest that such consumptive uses of wilderness as hunting and fishing are declining in proportion to total use; the more contemplative activities are increasing.

Trends

The small amount of research on trends provides little thoroughly supported knowledge. The effect of regional differences and variations among individual wildernesses may confound trends over time, and there are not enough studies of different types of wildernesses to disentangle geographical and temporal effects. However, some similar results have emerged that can be cautiously considered as relatively well supported.

First, the rate of increase of wilderness recreation use seems to be slowing down. There are indications that use may be leveling off, and maybe even dropping. In several places, National Park backcountry use seems to have peaked in the mid-1970's (van Wagtendonk and Benedict 1980), and National Forest wilderness use appears to have possibly peaked in the early 1980's (table 1).

The "designation effect"—the idea that labeling an area as wilderness stimulates use markedly—is often mentioned, but its significance is an unsettled issue. There is some evidence for such an effect, although probably not as strong as some might expect (Petersen 1981), and other evidence that the effect is certainly not inevitable (McCool 1985). Perhaps the force of designation is diluted because the number of wildernesses has grown so large—over 450—and so many new areas have been added recently—162 new National Forest wildernesses in 1984 alone, as well as other new wildernesses in the other wilderness-managing agencies. Any new area is likely to be publicized less and compete for visitation with more areas than was the case earlier.

A number of trends in the characteristics of wilderness use and users have been reported in most of the few trend studies. Use seems to be spreading out more (Lucas 1967, 1985b; van Wagtendonk 1981); stays most places are becoming shorter (Lucas 1967, 1985b; Cieslinski 1980) but were unchanged in Great Smoky Mountains National Park (Burde and Curran 1986). More visitors are coming from farther away (Lucas 1964b, 1985b); parties are becoming smaller (Cieslinski 1980; Corti and others 1982; Lucas 1985b; Burde and Curran 1986); fewer visitors have been to the study wilderness before (Corti and others 1982; Lucas 1985b); and there are more women visitors (van Wagtendonk 1981; Lucas 1985b). There are few major conflicts in results from these few studies, although most of the characteristics reported on are not included in more than one or two of the studies, making comparisons difficult.

The number of projection studies is too small to draw conclusions about agreement or disagreement regarding level of projected use. A variety of approaches have been used, and it is not clear that a final answer on the best method has been found. The two earliest projections agreed very closely with one another, probably due to lucky accident. These projections were a little high to 1976, but not bad considering the difficulties involved. The later studies project widely varying annual average rates of growth, from less than 1 percent (Hof and Kaiser 1983a, 1983b) (in their low scenario using figures for primitive, dispersed camping, hiking/backpacking, and horseback riding), to over 7 percent (Jungst and Countryman 1982). These rates of growth have vastly different results over time; in 40 years a 1-percent-per-year rate results in a 49-percent increase, while a 7-percent rate leads to 1,400-percent growth! There is no consensus on the magnitude of projections of wilderness recreation. Projections are unlikely to improve until use estimates are improved, research increases our understanding of the factors related to changes in use, and better projections of these factors become available.

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ATTITUDES TOWARD WILDERNESS AND FACTORS AFFECTING VISITOR BEHAVIOR: A STATE-OF-KNOWLEDGE REVIEW

George H. Stankey and Richard Schreyer

ABSTRACT

An understanding of user attitudes is essential to effective wilderness management. This review outlines historical and current societal and individual attitudes toward wilderness, reasons for participating in wilderness, factors affecting wilderness behavior (including attitudes toward management, crowding, and conflict), and how information and education affect behavior.

Visitors usually have distinct attitudes, though they vary considerably, and desire a role in the management process. Their views are increasingly important in the decision-making process. Research has a vital role in validating visitor input and presenting results to management in a timely and useful manner.

INTRODUCTION

How do people perceive wilderness? What factors influence their decisions to visit wilderness and what they do once there? What is the role of visitor attitudes and perceptions about wilderness in the management of these areas? Such questions underlie efforts to understand the meaning and significance of wilderness in society today.

In this paper, we review the state of knowledge regarding attitudes toward, and behavior within, wilderness. We are concerned with how people (typically, but not necessarily, visitors) feel about wilderness—the setting, use, and management. The actual behavior of wilderness recreationists—the types and lengths of trips, spatial and temporal patterns of use, and the activities in which people participate—is described in the review paper by Roggenbuck and Lucas (this proceedings). Our focus is on the factors that **influence** behavior—perception, education and information, group pressures, and so forth.

Because attitudes act as one influence on behavior, an understanding of their direction, intensity, strength, and distribution across the relevant population are all essential to effective wilderness management. Feedback from well-designed social surveys can provide a better understanding of the beliefs, ideas, and concerns held by visitors and other citizens. Such data also can help dispel the biases and misconceptions that arise from selective perception and contact (Lucas 1980).

We have focused our literature review on material dealing with the attitudes and behavior of individuals using environments characterized by relatively low use densities, few facilities, and where other resource development activities were prohibited or greatly restricted.

Many of the findings about the recreation behavior process that we report here have their roots in work done in nonwilderness settings. Wilderness and its visitors exist within a complex, interacting system of recreation environments; the institutional labels applied to such areas often have little bearing on how they are perceived and used. Movement within this system is fluid over both space and time. Indeed, it is the images and conceptions of wilderness and their influence upon visitors' use that serve as the focus of this review.

The presentation will initially examine the formation and evolution of societal attitudes toward wilderness. These broad, cultural conceptions have obvious influences on individual perceptions; they serve also to highlight the continually shifting nature of the perceived relationships between society and nature. We then shift to a more specific level of analysis, examining the motives underlying wilderness participation and the general question of why people seek out these settings (this issue is explored in more detail in the paper on wilderness benefits in these proceedings by Driver and others). We then explore environmental perception, focusing on how the images people have about wilderness are formed and modified and how they affect behavior. Next, we review the breadth and distribution of opinions held by wilderness recreationists toward management actions and policies that have been, or might be, implemented. Finally, our review examines conflict in the wilderness setting and the general literature on crowding and carrying capacity.

We close with a brief analysis of the extent to which research findings regarding attitude and behavior have been applied. We also suggest areas of needed research.

EVOLUTION OF SOCIETAL ATTITUDES TOWARD WILDERNESS

We begin our review of America's disposition toward wilderness at the society level. A society's conception of its environment and the relationship between itself and that environment are a product of a variety of experiences and influences. The attitudes about, and the behavior toward, wilderness in the United States reflect this: to fully understand modern society's view of wilderness, one needs to understand something of the socio-cultural history out of which the country and its people evolved.

Early Conceptions of Wilderness

Nash's "Wilderness and the American Mind" (1982) provided us with an excellent summary of Old World images of wilderness that served as a frame of reference for early American colonists. Although wilderness, in American terms, exists in only a few isolated places in modern Europe, during the Middle Ages it was a significant and familiar component of the landscape. But it was less the physical familiarity with wild lands and more the place of wilderness in mythology and religion that shaped the common view of wilderness.

In the simplest sense, wilderness was the antonym of paradise. Whereas paradise was ordered, beneficent, and supportive of the human way, wilderness was foreboding, evil, and threatening. This image was communicated and reinforced through various media; both classical mythology and the folklore of various European tribes conveyed the idea of wilderness as a place beyond human control, a place of demons, monsters, and devils, of strange, grotesque beasts. Indeed, it is in the epic Anglo-Saxon story of Beowulf that we encounter use of the word "wildeor," a wild animal, which Nash identified as the etymological root of "wild-deor-ness," the place of wild beasts, and eventually the word wilderness.

Certainly the Biblical use of wilderness further reinforced such negative connotations. From the downfall of Adam and Eve and their banishment from the garden (paradise) to the 40-year wanderings of Moses and the Israelites in the Sinai Peninsula, wilderness described the setting to which individuals were exiled.

Yet, these early episodes also contain the first hint of a countervailing attitude toward wilderness. Added to the traditionally accepted dreadful image of wilderness was the idea that wilderness was a place where one could seek sanctuary from a fallen society, where one could find God, and where people could be purged and cleansed prior to finding the Promised Land. All these images conceived of wilderness not as a place of worth or merit itself, but rather as a means of achieving paradise. They represented the recognition of utility and value of wilderness, contrasted to the negative images typically associated with it.

As the European population grew and agriculture and industrialization spread, the wilderness landscape rapidly diminished. Although the rate of change varied throughout the area, it is generally agreed that the changes occurred sufficiently fast so that the forests of the region often did not reach equilibrium with the climate before they were destroyed or modified by human action (Poore and Gryn-Ambroes 1980). Conceptions and images of wilderness carried by early American colonists were strongly influenced by the religious dogma that dominated their culture. In many ways, the worst fears of these early settlers were realized when they first came in contact with the North American wilderness. The sheer immensity of it was beyond anything they could believe. The few remnants of wild land remaining in Europe were restricted to small, discrete pieces of country—a peak or a valley. In America, it stretched on endlessly. It was not only a physical barrier to movement, but it also harbored wild animals, Indians, and other threats. In a variety of ways, the American wilderness fit to perfection the belief, fabricated over generations in Europe, of a place that harbored anti-Christian forces. Perhaps even more serious than its role as a barrier to progress or as a sanctuary for forces threatening to settlers was its capacity to lead man to succumb to the wildness of his surroundings (Graber 1976). Unless constant vigil was maintained, the thin veneer of civilization could be lost, reducing man to a condition, as one early writer noted, "no better than carnivorous animals of a superior rank" (Nash 1982).

The early conception of wilderness in North America was dominated by fear and abhorrence. Period literature is full of references to wilderness as desolate, a howling wasteland, a godless tract. Although these accounts are derived from a relatively small segment of the society, they are typically the opinions of key community leaders, particularly spokesmen of the religious institutions. There seems little reason to believe that the North American wilderness held much for early settlers other than fear and foreboding.

But attitudes are not static. Attitudes are the product of a variety of influences and conditions and, as these change, attitudes change as well. As eastern seaboard settlement took root and westward expansion occurred, the image of wilderness evolved further.

Shifting Attitudes Toward Wilderness

These tentative changes in attitude were not the forerunners of a major revolution in thinking about wilderness (Dearden and Sewell 1985). They do constitute a point at which ambivalence again began to emerge; wilderness was seen not only in its traditional role as a barrier to progress and a potential contaminant of the human spirit but also as a source of some more positive human value. What began to emerge as America grew was a view, albeit a minority perspective, that the wilderness landscape held value in and of itself, that it was not just the material from which civilization was to be fabricated. Nash (1982) noted that the concept of sublimity gained widespread usage in the 18th century. In the spirit of that age, the wilderness setting was considered pleasing, and emotional reactions to it were ones of awe and exultation rather than dread and loathing.

This tentative shift represents a critical point in our history; the symbolic representation of wilderness began to change. As Tuan (1974) has noted, the human capacity for symbolic behavior is great. For generations, wilderness was a symbolic manifestation of a great many things contrary to human welfare. As the 19th century began to unfold, we see, if not a rejection of this symbolism, at least a differentiation in it. This change raises questions as to what factors might have been responsible for such a reorientation. A review of this era's history suggests several possibilities.

First, this period marked a time of rapid growth in scientific understanding. Actually, beginning in the 11th century, the scientific sector of European culture had increased greatly (White 1967). With it came an increasing understanding of the world and evidence that natural phenomena such as mountains and storms were not the result of a vengeful God's wrath, but rather the end product of predictable physical laws and processes. Growth of

scientific understanding helped generate an appreciation of how nature in general, and wilderness in particular, revealed the glories of God; it contributed to a major shift from the traditional view in which such areas were seen as indicative of an absence of holy influence (Huth 1957).

Second, several authors have argued that the emergence of an appreciation for the vast wilderness of North America was the result of the search for a distinctive American culture (Lowenthal 1968; Nash 1982). Because the country's youthfulness largely precluded significant achievements in art or literature, America's cultural development was meager compared to that of Europe, and the lack of such accomplishments could not be fully offset by the new nation's flourishing economy or stable government. But ironically, the art and literature of the romanticists, much of it created by Europeans, helped generate an appreciative attitude regarding nature. Increasingly, Americans came to realize that a distinctive aspect of their culture was one not only absent from Europe, but one not even capable of being created there: vast, unfettered nature, represented in the wilderness of North America. Gradually a notion that appreciated certain values of wilderness began to take form.

A third factor was the gradual emergence of an urban population. At the onset of American settlement, pioneers confronted wilderness in a direct manner; there was no buffer to soften the impact, and survival was paramount. The lack of any deep affection for the raw natural surroundings against which they found themselves pitted was hardly surprising. But as distance between mainstream society and the wilderness frontier began to increase, so did the capacity for an appreciative stance, spurred by factors such as the rise of romanticism.

The beginning of westward expansion also marked the beginning of the diminution of what once was considered an endless tract of wilderness. The finiteness of wilderness and the fact that it could become scarce found its way into the American psyche, an important precondition to the recognition of wilderness as a public good (McCloskey 1966).

Although these changes in attitude did not constitute broad, pervasive shifts in public opinion, they were significant. They set the stage for a period during which recognition of wilderness values began to be supplemented by actions in the public policy arena.

The 1800's marked a significant turning point in America's relationship to wilderness. This shift turned on two fronts. First, there was continuing growth in the intellectual conceptualization of wilderness and its relationship to human society. Romanticism played a key role in this development; it viewed wilderness as sublime and a physical reality vital to society. As Nash (1982) noted, however, romanticism never seriously challenged the dominant pioneer attitudes toward wilderness; it merely provided momentary respite from the general antipathy toward such areas. Romanticism did not reject man's long-term dominating stance toward wild nature; it required only recognition of a broadened symbolic wilderness in which the beauty of such areas and their strengthening qualities to the human spirit were admitted.

Belief in a more fundamental function for wilderness relative to society contributed to a rise in the transcendentalist view. Transcendentalism implied that a higher realm of spiritual truth paralleled the plane at which material reality existed and that it was possible, through intuition or imagination, for an individual to achieve this higher plane of consciousness. The more unfettered and uncontaminated the natural setting, the better it could facilitate spiritual insight and moral improvement.

Transcendentalism is well represented in the writings of Thoreau. Thoreau encapsulated this philosophical stance when he pronounced, in 1851, that "in Wildness is the preservation of the world." Wildness and its physical manifestation as wilderness, in the view of the transcendentalists, were essential to society's understanding of its relationship to God. In a reversal of earlier Puritan views, the inherent goodness of mankind could only be realized through the presence of wild nature.

Thus, the first major development in the 19th century that set the stage for a societal shift in attitude toward wilderness was the formulation of a philosophical framework within which such areas could be defined as contributing to human welfare. Although such a framework did not enjoy universal acceptance, it provided an alternative perspective that would serve as the basis for later, more profound alterations in America's view of preservation.

The second major activity in the 1800's involved the first calls for action to preserve wilderness. Twenty years prior to Thoreau's famous pronouncement, George Catlin, a lawyer, painter, and student of the American Indian, had introduced the concept of "a nation's Park, containing man and beast, in all the wildness and freshness of their nature's beauty" (cited in Nash 1982). Catlin's remarks were motivated both by his observation of the rapid disappearance of the wilderness as well as his concern with the contaminating influences of civilization on the wilderness.

Such pronouncements raised the issue of protection of wilderness values to a public, and therefore, political level. Calls for protection began to find realization in the second half of the 19th century. In 1864, the Federal government granted the State of California lands in Yosemite Valley for the purpose of preservation. In 1872, Yellowstone National Park was established as the world's first such reserve. It was followed in 1885 with creation of the Adirondack Forest Preserve by the State of New York, and in 1890, by Yosemite National Park, according to Nash (1982) the first park consciously designed to preserve wilderness.

Wilderness preservation was not the primary motivating factor for early protection. In the case of Yellowstone, designation was to prevent the area's "curiosities" from being taken up in private ownership while in the Adirondacks protection of valuable watersheds was the principal concern. Even in the case of Yosemite, the enabling legislation did not contain specific language citing wilderness preservation as an objective.

Much of this early action focused on the protection of areas with special qualities, such as the thermal features of Yellowstone, rather than on the protection of large tracts of undeveloped land that lacked any distinguishing values other than their naturalness. Even when protection was provided, support in the form of Congressional appropriations was often lacking. Without the intervention of the U.S. Cavalry, several National Parks, including

Yellowstone, Yosemite, and Sequoia, would have been exploited in the latter part of the 19th century (Hampton 1971).

Nonetheless, these actions provide evidence of a major revamping of social values, a shift of amazing proportions, because only a few decades earlier such actions likely would not have been even considered, let alone undertaken.

The ambivalence permeating evolving philosophical and religious thought over the years also was reflected in the policies of government. At the same time that precedent-setting actions of preservation were taking place, traditional views of progress and development were further codified through a variety of government policies and laws. These included the Pre-emption Act of 1841, the various Homestead Acts beginning in 1862, the General Mining Law of 1872, the Timber Culture Act of 1873, and the Desert Land Act of 1878. Such actions helped sustain not only the physical occupancy of the wilderness, but also reinforced the attitude that the Nation's duty was to subdue and develop remaining wild lands.

From roughly the last decade of the 19th century through the first two decades of the 20th century, a great transition occurred in America's attitude toward wilderness. Over this time, the negative evaluation of wilderness and support for its elimination were replaced by significant concern that at least some wilderness should be preserved.

This period of transition featured a gradual rethinking of the relationship between wilderness and society, characterized then, as well as now, by conflicting interests and competing values of the worth of wilderness. What was significant in this shift was the emerging view that the struggle between wilderness and civilization was not a matter of a conflict between good and evil but rather a debate over two goods, with resolution based on a judgment of the relative priorities associated with each.

The place of wilderness on the national agenda, in a historical sense, altered with amazing speed. What were the driving forces that underlay this shift? Why, in the 1850's, did Thoreau find little receptiveness for his views about the role of wilderness in civilization, yet in 1913, John Muir and Robert Underwood Johnson were able to elevate the Hetch Hetchy controversy into a major national issue, commanding the personal attention of the President?

Wilderness in 20th-Century America

At least three merging phenomena of late 19th-century and early 20th-century America help explain much of our new view of wilderness. First, the seemingly unending wilderness against which significant struggle was required in order to establish European-style civilization was simply disappearing. With the 1890 Census, the frontier was officially declared gone and, with it, the environmental conditions that had spawned much of the unique American character. Moreover, there was no need to maintain the antagonistic relationship with wilderness; westernization had won. Second, the intellectual and emotional base for the support of wilderness from scientific, philosophical, and religious perspectives had undergone great change during the latter 1800's. Increasingly, good reasons from a variety of perspectives could be offered in support of wilderness. Third, America was undergoing the growing pains of an emerging industrial civilization and many of the aspects of this new society were distressing. The slums, the squalor, the dehumanizing treatment of industrial workers all contributed to a rising concern that too much civilization, like too much wilderness, was not a good thing, and that as the distance from our wilderness origins increased, so did the need for continued contact with such settings.

With the momentous changes in the American landscape and society in the late 1800's, the period around the turn of the century was pivotal for wilderness support. Activity supporting the goals of preservation could be found in both the public and private sector. In 1892, for example, Muir, along with several professors from the University of California and Stanford, established the Sierra Club. It followed the precedent, established nearly 20 years earlier by the Appalachian Mountain Club, of uniting people with an interest in the out-of-doors. Although only one of several such organizations founded during this period, it clearly laid out its concern by mobilizing public support for governmental action to preserve the environment.

In 1916, the creation of the National Park Service represented a significant, long-term commitment by government to ensure protection of segments of primitive America and was an important consequence of the earlier steps taken to preserve Yellowstone and Yosemite. This action was in part due to growing public concerns with protection of natural values. In large part, however, it was a result of vigorous efforts by Stephen Mather to secure support for creation of the agency among key opinion leaders across the Nation. Between Mather and Robert Sterling Yard, over 1,000 magazine articles were published in support of the National Parks in 2 years and 275,000 copies of an illustrated book about the parks were distributed free to the Nation's opinion leaders (Fazio and Gilbert 1981).

Such a broad-scale shift in public and governmental attitudes was essential to any substantial growth in the wilderness idea. As Nash (1982) noted, possibly the significance of the Hetch Hetchy controversy is less the particular outcome of the debate than the fact that it occurred at all. Although conflicts remained and would continue, early 20th-century America had reached a point where the preservation of wilderness was increasingly viewed as important. From the 1920's until the present, the long-developing positive conception of wilderness in America gained broad public support.

The 60-year period between 1924 and the present can be broken into two subunits in terms of attitudes toward wilderness preservation. Between 1924 and 1964, there was an increasing maturation in the wilderness concept, expansion in public support, and growth in the role of government in wilderness preservation, and in its institutionalization as a land use. The period was initiated by the landmark reservation in 1924 of the 574,000-acre Gila Wilderness in New Mexico, largely through the efforts of Aldo Leopold. This action represented the first formal dedication of an area to wilderness purposes, setting the stage for creation of a system of land use reservations

that would match the National Park System in terms of its international precedence and significance.

The Gila Wilderness designation was followed shortly by a major inventory of remaining wilderness lands in the continental United States. The results confirmed that wilderness was diminishing. Such information provided support for creation of the first formal and systematic organizational program to achieve wilderness preservation goals—the L-20 program instituted by the Forest Service in 1929. Deeply imbedded reservations about wilderness remained, and it is interesting to note that the L-20 program created a system of "primitive areas" rather than wilderness areas, a step purposely taken because of concerns about public opposition to the establishment of wilderness. Ten years later, efforts by Bob Marshall, the dynamic and imaginative proponent of wilderness and then Director of Recreation for the Forest Service, led to a revised set of administrative procedures for the establishment and protection of a system of wilderness and wild areas on the National Forests. This new system was intended to gradually replace the earlier L-20 program and provide a more rigorous approach to wilderness preservation. Formerly permitted developmental activities were more tightly regulated and wilderness preservation purposes more clearly defined (Hendee and others 1978).

In approximately one decade, from institution of the L-20 regulation until the outbreak of World War II, over 14 million acres were set aside as wilderness on the National Forests. Additionally, the first explicit recognition of wilderness values was written into the enabling legislation for Everglades National Park. Clearly, the concept of wilderness had obtained a credibility sufficient to establish it as a legitimate value and land use. Rather than being an assumed or implicit quality, it now received recognition in and of itself.

However, the recurring theme of conflicting societal goals soon reasserted itself. Following the end of World War II, increasing demands, especially on the National Forests, for timber products soon brought the goals of a developing and expanding society into conflict with those of preservation. A similar kind of conflict, albeit different in form, occurred in the National Parks, as use levels and demands for services grew rapidly. Many felt that wilderness was considered only as a residual value and that when conflicts with traditional values and uses arose, wilderness would always lose. Moreover, the establishment of new wildernesses appeared viable only if it could be demonstrated that such areas did not involve the loss of any significant monetary values. Wilderness protection was a defensive activity, dependent on the good will and discretion of sympathetic administrators.

Concerns with the long-term protection of wilderness reached a peak in the mid-1950's with introduction of the initial bill to establish a National Wilderness Preservation System. In the ensuing 8 years, any doubts that wilderness had achieved broad recognition and support as a political issue were dispelled. Its tenacity was impressive; it reappeared with each Congressional session over 8 years, each time with more force. The wilderness issue and its supporters became intensely politicized. Literally thousands of pages of testimony were received, hearings were held nationwide, and Congress was flooded with letters, resolutions, and petitions. Few, if any, items had ever received the level of public attention over such an extended period. Moreover, it was a time when wilderness advocacy groups acquired new levels of skill and expertise in dealing in the political arena, skills they would later use to even greater advantage. When the final wilderness bill was voted on, both Houses of Congress passed it with overwhelming majorities (see Allin 1982 for details of the Congressional debate over the Wilderness Act).

Passage of the Wilderness Act in 1964 constituted support for wilderness at the highest level of government and represented a transition to the second period in the recent history of wilderness. If one assumes that the actions of Congress reflect an estimation on that body's part of the interests and needs of American society, it is clear that an extraordinary shift in American attitude toward wilderness had occurred over a period of scarcely more than a century. The act represents an expression of nationwide support for the concept of wilderness as well as an expression of society's intent to back that attitude with action. As we shift attention to the second component of our recent historical review, the period from 1964 until the present, we will examine some indicators of this intention that reflect American attitudes and behavior with regard to wilderness.

At the time the Wilderness Act passed, more than 9 million acres were included in the National Wilderness Preservation System (NWPS). It was not clear how much wilderness might eventually be set aside, although Howard Zahniser, the Wilderness Society's principal architect of the act, estimated that perhaps 50 million acres might be included (Nash 1982). However, at the end of 1984, two decades after passage of the act, the NWPS had swollen to nearly 89 million acres, with the designation of many millions more pending. Over 60 separate pieces of legislation had worked through the elaborate and, at times, tortuous Congressional approval system to reach final passage. The NWPS has continued to grow, even though a wide spectrum of political ideologies have been represented in Congress as well as the White House. This virtual tenfold expansion in classified wilderness in 20 years is an impressive manifestation of the priority of wilderness on the national political agenda and its remarkable capacity to sustain itself in the minds of politicians and the public.

The political significance of wilderness has ensured that it remain a major concern for administrative agencies. For example, in less than one decade the Forest Service has undertaken two major reviews of the extent of roadless, undeveloped lands in the National Forest System, with the objective of recommending to Congress new additions to the NWPS. Both reviews (Roadless Area Review and Evaluation, RARE I and II) have been expensive, time-consuming efforts; public demands for information as well as high-quality performance in the conduct of these reviews have been considerable. During RARE I, for example, 300 public meetings were held nationwide, with over 25,000 persons in attendance. Public input included 54,000 individual and/or group opinions, and 18,000 signatures on petitions. During RARE II, 5 years later, over one-quarter million inputs were received, containing over 360,000 signatures.

Similar intense public interest has been witnessed for wilderness issues in the National Parks. The General Management Plan for Yosemite National Park, for example, where substantial wilderness values are found, generated tremendous public involvement. The National Park Service conducted 48 workshops nationally, drawing 5,600 participants. An elaborate workbook was devised in which various management alternatives were outlined, along with a section where citizens could devise their own management alternative. Over 700 possible choices were involved and the average time to complete the workbook was estimated between 4 and 8 hours; nonetheless, 21,000 of the 60,000 distributed were completed and returned (Buck n.d.).

Summary

If we summarize the evolution of American attitudes toward wilderness over the past 250 years, several themes emerge. First, there has been a remarkable shift in those attitudes since the eastern seaboard was first settled by Europeans. Although the trend has not been even, the general tendency has been for a continually evolving conception that recognizes the importance of wilderness. The evolution has been driven by a variety of forces, including shifts of thinking among both scientists and philosophers, the increasing scarcity of wild land, and recognition of the value of retaining a diversity of environmental settings as a complement to an increasingly developed landscape.

Second, nature in general and wilderness in particular have commanded a central position on the political agenda. Wilderness has clearly achieved the status of a major public policy issue in America. While other issues will command attention from time to time, the importance of wilderness, especially its future stewardship, will remain a major concern.

Finally, the attitudes that society holds about wilderness, as well as those espoused by visitors to such areas, are critical to the planning and management of such areas. Therefore, science has a major responsibility to provide politicians, managers, and the citizenry with a comprehensive, accurate information base regarding these attitudes—their range, strength, and distribution—in order to facilitate the long-term preservation of wilderness.

Such attitudes include overall societal support for the concept of wilderness, factors influencing where to go as well as what to do while in wilderness, attitudes toward management, and the perception of other wilderness users. The next section examines factors affecting decisions about participation in wilderness recreation.

REASONS FOR PARTICIPATION IN WILDERNESS RECREATION

The overall purpose of this review is to explore the factors that influence people's attitudes about wilderness and their subsequent behavior in such areas. We want to understand better the "why's" behind these attitudes and behaviors. In the previous section we examined general societal views of the **concept** of wilderness. Now we want to take a closer look at specific attitudes and behaviors as they relate to actual wilderness use. In this section, we examine the factors that lead people to visit wilderness and affect their decision to participate.

The reason for wanting to participate is generally considered the motive for behavior. This motive must be translated to behavior through some choice process, which can be influenced by many situational factors. The object of choice might be a particular recreation environment, a behavior, or some desired psychological condition. The selection of a particular wilderness environment depends on the attributes in the environment perceived as being suitable for fulfilling the needs that initially motivated behavior. These three components—the motives that initiate behavior, the choice process to determine the type of behavior, and the attributes of environment that affect the place selected for behavior—will be discussed below.

Motives for Participation

The Semantics of Motivation.—Research on the topic of motivation in recreation has been filled with ambiguity. Different terms have been used to describe the forces initiating human behavior. We often say that people behave primarily to fulfill needs, and that a need represents a condition of human consciousness in which the individual perceives a relative deprivation in some aspect of existence. The concept of need is very plastic, ranging from universally shared needs, such as for food, to extremely individualized and contrived needs, such as for a video cassette recorder. Thus, the concept of need is a very broad way of representing forces that direct persons toward action with greater or lesser intensity.

A motive is considered to be a more or less consistent predisposition to act on a certain type or set of needs. The extent to which a given motive will direct behavior depends on the amount of perceived deprivation. Individuals can have a motive to experience nature that will direct them toward the selection of recreation activities in natural environments. This can result in an ongoing pattern of participation, but may have greater or lesser influence on any given decision.

Motives, like needs, are contrived notions. We can generate lists of motives for participation, and they might be more or less consistent over time. There is likely no universal list of motives, however, and the reasons for participation evolve as cultural and individual values evolve. Motives are a useful form of shorthand for representing the reasons why people engage in a certain type of behavior.

Reasons for engaging in recreation behavior have been conceived as "recreation experience preferences" (Driver 1976), in recognition of the fact that the forces that initiate behavior are voluntary and represent preferred conditions. If a certain need initiates behavior, we want that behavior to provide us with a payoff in terms of fulfilling that need. We walk into the wilderness because we have the desire to experience nature; thus, it is important that we do in fact experience nature. This payoff is seen as an outcome, and is why motives have also been referred to as "desired psychological outcomes" (Driver and Brown 1978) or "desired consequences" (Driver and Knopf 1977).

A particular behavior and environment are chosen in response to a given motivation primarily because the information available at that time leads us to expect that such

behavior and environment will, in fact, produce the desired outcome. Thus, we participate in recreation with some expectation that we will encounter desirable conditions. This is why motives have also been represented as "experience expectations" (Schreyer and Roggenbuck 1978).

Needs, motives, experience expectations, recreation experience preferences, and desired psychological outcomes all represent slightly different ways of looking at the purpose that engaging in a given type of recreation is supposed to serve (Crandall 1980). Measurement of the extent to which these outcomes are attained is usually represented as satisfaction. If the expected outcomes are not forthcoming, the person is assumed to be dissatisfied with the recreation experience.

The outcomes provided through participation in a given environment provide insights into the psychological function of that particular type of recreation for the individual and, consequently, help establish the value of a particular use of a given environment. The paper "Benefits of Wilderness Participation" (Driver and others this proceedings) focuses on these payoffs. In this paper we focus primarily on reasons for the initiation of participation, though the forces cannot be separated completely.

Theoretical Approaches.—Recreation research on motivation has drawn on existing models from the psychological literature. The most frequently used model has been expectancy theory (Lawler 1973), in which the force behind a given behavior is a function of the strength of expectancy that an outcome will result from a particular behavior in a given environment and the value of that outcome to the individual. One of the earliest users of expectancy models was Peterson (1974b), who explored the role of expectations and actually perceived conditions in the satisfactions of Boundary Waters Canoe Area recreationists. Roggenbuck (1975) used a similar approach to studying perceptions of whitewater river floaters in the backcountry of Dinosaur National Monument. Similar expectancy studies of whitewater floaters have been conducted in Desolation and Westwater Canyons in Utah (Schreyer and Nielson 1978) and on the Rio Grande River in Big Bend National Park (Graefe 1977). Rossman and Ulehla (1977) also explored the importance of wilderness environments for providing need-satisfying outcomes. Such studies underscored the significance of visitor expectations in influencing the wilderness experience, especially with regard to effects on the perception of objective conditions in the environment.

More recently, some researchers have attempted to use the more elaborate model of Fishbein and Ajzen (1975). This model includes a normative component in which behavioral intention is a function of the perceptions of significant others' expectations that a person should engage in a given behavior, and the individual's motivation to comply with the wishes of those other persons. This approach was used with limited success by Cockrell and McLaughlin (1979) to predict the environmental selections of whitewater river recreationists. While the complexity of the model has been a barrier to many researchers, the two areas of expectations and social norms have been major elements in research on understanding wilderness visitor attitudes and behavior.

General Motives.—Many studies have examined motives for participation in wilderness. Early studies were not geared toward a standardized measure of motive but asked visitors why they had chosen a given area. For instance, Bultena and Taves (1961) found Quetico Provincial Park visitors seeking opportunities to struggle with the elements, to get away from artificial settings, to explore, and to gain new experiences and personal gratification through realizing one's full capabilities. Most visitors were fishing, but the major rationale for visiting appeared to be not so much to catch fish as to be in a primitive and undisturbed area.

Lucas' classic study of Boundary Waters Canoe Area users (1964b) showed that people visited the area for reasons of solitude, to be with members of one's group, to learn about the area, and to commune with nature. Catton (1969) generalized about wilderness motives, particularly in terms of variations across different types of users. For instance, mountain climbers sought the opportunity to act in the face of uncertainty of success. In contrast, easy-access campers appeared to be seeking freedom from tension, from responsibility for the consequences of one's actions, and from parental duties. Catton noted that the desire for social interaction was often a strong motivator for participation, but so was privacy. Finally, Catton suggested that wilderness is valued for the "intellectual puzzles" that nature presents, which is why more highly educated people might be attracted to wilderness.

Although it would be possible to generate long lists of motives from numerous studies, it seems more useful to pursue generalizable consistencies in observations. One motive traditionally associated with wilderness use is solitude. While solitude is a part of the wilderness concept as defined by Congress, research indicates that the concept is not simple to interpret. Persons seeking solitude may likely be in the presence of others but seeking seclusion, anonymity (Twight and others 1981), or shared intimacy (Lee 1977). Hammitt (1982) found four dimensions to the concept of solitude in wilderness: natural environment, cognitive freedom, intimacy, and individualism. In a related effort, Hammitt and Brown (1984) found five dimensions related to the pursuit of privacy in wilderness: emotional release, personal autonomy, reflective thought, personal distance, and intimacy. It appears that what is generally described as solitude really covers a number of motives.

While people value sharing the wilderness experience with others, this is not a reason for wilderness participation as such. The social dimension is something that goes across the range of recreation participation and is not unique to the wilderness experience. Research on wilderness motives tends to show that although social reasons are often cited, they are generally less important than other motives (Shafer and Mietz 1969; Rossman and Ulehla 1977; Feingold 1979; Brown and Haas 1980). Similarly, although the escape motive is strong in wilderness participation, escapism is also a motive for other outdoor recreation activities (Driver and Knopf 1976).

Another dimension reported regularly in studies on wilderness is one that would appear to be obvious: appreciation of the natural environment. Beyond the nature experience and the pursuit of solitude, few other dimensions

of motivation appear to be shared as consistently across studies (Kaplan and Talbot 1983).

While we seek common reasons for wilderness participation, we are aware there is considerable diversity in the reasons held by visitors. We next review the factors underlying these differences. First, we examine motivations linked to the type of activity pursued; people can have very different reasons for pursuing different types of activities, even though they all take place in a wilderness setting. Next, we examine differences across patterns of participation. We then look at the influence of the individual's background characteristics on motivation for participation. There are also potential combinations of motives for participation and these are also reviewed. Finally, we will look at how visitors to different wilderness settings vary in their motives.

Activity-Centered Motives.—The activity most strongly linked to wilderness participation is hiking. Lucas (1971) suggested that esthetic values—the enjoyment of scenery and contact with nature—were the most important motives for participation, exceeding exercise, socializing, or specific activities. He also noted that the esthetic response was more emotional or romantic than intellectual or educational. Temporary escape was seen to be a major theme.

Studies on hikers carried out in the East (Bowley 1979; Knopf 1983) and West (Brown and Haas 1980; Haas and others 1980b) tend to reflect similar results. Wellman and others (1982) identified significant differences in the rated importance by hikers of certain motives in Shenandoah National Park and park managers' predictions of those motives. The importance of motives to meet and observe new people, to learn and experience nature, to enjoy scenery, to reflect on personal values, and to express creativity is often underestimated. Thus, it might not be enough to observe that a motive is present. Rather, it is important to note the relative intensity of that motive (Brown and Haas 1980).

Bultena and Klessig (1969) provided a conceptual overview of the satisfactions derived from camping. They claimed that motives pointed toward benefits that could be derived specifically from the resource, rather than from mere change of pace or setting. They also argued that camping emphasizes the primitive, an "activistic" orientation, the search for a personal experience, and intrinsic rather than status-oriented goals. In a study oriented specifically toward the motives of campers, Hollender (1977) found important factors to be "primitive lifestyle," escape from responsibilities, esthetics of the natural environment, and escape from urban stress.

Motives for fishing have been explored in wildland settings (Driver and Cooksey 1977). Studies typically reveal that psychological motives are more important than the specific product pursued; that is, anglers seek the opportunity to relax, achieve, and socialize more than they value the fish (Knopf and others 1973; Kennedy and Brown 1976; Hendee and others 1977; Manfredo and others 1978; Knopf 1983).

Studies of hunters echo similar themes. More (1973) showed that hunters value the display of equipment, the desire to be outdoors, shared experiences with companions, escape, and challenge. Display of game and the enjoyment of eating it were also important. Other studies have shown the importance of escape, exercise, and companionship, and the lesser importance of actually harvesting game (Hautaluoma and Brown 1978; Hautaluoma and others 1982).

More specialized activities, such as cross-country skiing (Haas and others 1980a) and mountain climbing (Ewert 1984), have also been examined. Perhaps the most widely studied specialized activity is whitewater river floating. Roggenbuck (1975) and Schreyer and others (1976) found that the most important factors for floaters in Dinosaur National Monument were action/excitement, learning about nature, stress release/solitude, and affiliation. Similar results were found on the Rio Grande River in Big Bend National Park by Graefe (1977) and Ditton and others (1981), and in Desolation and Westwater Canyons in Utah by Schreyer and Nielson (1978). The motive studies on rivers invariably show outcomes similar to terrestrial situations, with the addition of motives related to action and excitement reflecting the whitewater component.

Finally, some studies have attempted to compare motives across different types of users of the same environment. Bassett and others (1972) compared the motives of trout fishermen and canoeists. In perhaps the most elaborate comparison of different types of users, Brown (1981) compared motives among backpackers, hikers, campers, fishermen, hunters, river runners, and cross-country skiers. He showed that motives common to all were relationships with nature, escape from social pressures, and being with one's recreation group.

In summary, although there are differences across activities in terms of specific motives or the relative intensity with which motives are held, there is nonetheless considerable agreement among visitors about the reasons for wilderness participation.

Patterns of Participation and Motivation.—It is likely persons with different motives pursue wilderness recreation in different ways. Roggenbuck (1975) and Schreyer and others (1976) compared persons floating the Green and Yampa Rivers through Dinosaur National Monument who exhibited different trip characteristics: day to overnight users, paddle trips to oar-powered trips, and commercial to private and educational trips. In each case, significant differences in motivation were noted.

Similarly, Ditton (1979) compared the motives of local to nonlocal floaters on the Buffalo National River and found significant differences in virtually all cases. Hammitt and Loy (1982) compared winter to summer visitors to the backcountry of Great Smoky Mountains National Park. They found winter visitors sought to avoid summer crowds and experience the winter environment.

Background Characteristics and Motivation.—Differences in motivation resulting in different patterns of participation in the same activity can be seen as the result of variation in background characteristics of the individual. For instance, Driver and Knopf (1976) linked differences in intensity of motivation to personality attributes.

A person's attitude toward the environment is another source of variation in motivation. Schreyer and others (1981) asked visitors to the backcountry of Canyonlands National Park whether they came because they liked the park itself, or because it was a good place to do their

favorite activity. Significant differences were found between the two types of visitors in their motives for participation: those who liked the park itself were more interested in general learning and less interested in social recognition, testing one's skills, stimulation, being with friends, or tension release, than those who visited the park to pursue their favorite activity.

One background characteristic that has been explored in some detail is the amount of previous experience an individual has had in the activity. This variable has been used primarily with respect to whitewater river floaters; however, other types of wilderness participation have been similarly studied. McCool and Haydock (1976) examined differences in motives of hikers of the Virgin River Narrows in Zion National Park, based on differences in amount of experience. They found that experienced users tend to value escape more, and are less strong in their desire for action or excitement.

Differences in motive intensity related to previous experience have been shown in river settings by Roggenbuck (1975) and Schreyer and others (1976) in Dinosaur National Monument, in Desolation and Westwater Canyons in Utah (Schreyer and Nielson 1978), and on the Buffalo National River (Ditton 1981). In addition to intensity of motive, Schreyer (1982) showed there were differences in the specificity with which river runners stated their reasons for participation. Experienced users tended to be more detailed and specific in stating their expectations.

Previous experience can be defined in different ways. Schreyer and Lime (1984) showed that differences in motivation depended on whether experience was measured on the particular river being floated or experience in river running in general. To characterize the nature of this complexity, Schreyer and others (1984) created a six-category measure of "experience use history" to represent previous participation on the study river, on rivers in general, and the total number of different rivers run. Persons in the different categories showed different motive profiles for engaging in the activity.

Clusters of Motives.—Many motives influence the decision to participate in wilderness recreation. They vary considerably in relative intensity. To deal with this complexity more efficiently, researchers have attempted to classify people by shared groups of motives. Bowley (1979) distinguished two types of users based on differences in motives for affiliation, arousal, escape, and self-awareness. Using a clustering routine, Haas (1979) identified five "experience types" among hikers in three Colorado wilderness areas. Manfredo (1979) used a similar approach to identify three different experience types in wilderness areas in Wyoming. The fact that these studies identified different numbers of types illustrates the complexity in variation of motivation. Although people can share similarities in motivation, it is unlikely that specific, discrete "types" of wilderness recreationists can be defined.

Setting Types.—We assume that recreationists select different settings in which to pursue wilderness recreation because different motives for participation require different types of environments to fulfill perceived needs (Driver and Brown 1978). Thus, if one were to study different wilderness environments, variation in the relative importance of different motives for participation would be expected.

Haas (1979) compared types of backpackers, as mentioned above, across the Weminuche, Rawah, and Eagles Nest Wildernesses in Colorado. Having created five experience types for each area (a total of 15), he found that 10 of the types were unique to the various areas, while two were common across all areas and another was common across two areas. In contrast, Brown (1981) compared the motives of hikers, fishermen, and wilderness backpackers in the East and the West. While some differences emerged, the participants were more alike than different in motive profiles.

Williams and Schreyer (1981) compared the motives of visitors to the High Uintas Wilderness in Utah to those of visitors to the backcountry of Canyonlands National Park, also in Utah. The former area is characterized by alpine settings, while the latter is desert/canyon topography. Visitors to the desert placed more importance on tension release, competence testing, escape, and family togetherness than their counterparts in the mountains.

In river settings, Schreyer and Nielson (1978) compared the motives of floaters in Desolation Canyon on the Green River and Westwater Canyon on the Colorado River, both in Utah. While studies show statistically significant differences in the motives of recreationists in different settings, there is some question as to how big those differences really are. Knopf and others (1983) compared the motives of floaters on 11 different rivers across the Nation. They concluded that while differences across the rivers were noted, the motive profiles were more similar than they were different.

In summary, a variety of motives underlie wilderness recreation participation. Many of these motives are linked to opportunities typically associated with wilderness, such as the desire for escape and solitude, appreciation of esthetics and naturalness, and challenge and risk taking. Others, however, are less integrally associated with wilderness: meeting and observing others, making new friends, and various status-related motives are important for many visitors. Although typically less prominent than the former, these latter motives help improve our understanding of the "why" of wilderness participation.

Research also suggests that our conceptions of motives may often be oversimplified, particularly when we try to translate them directly into guidelines for management. Solitude is an excellent example; frequently cited as a measure of intergroup contact, it is in fact a complex construct that involves a variety of measures people use to regulate access to themselves (Altman 1975). Depending on its specific conceptualization, definition of the relevant measure and its implications for wilderness management will vary greatly. It seems likely that other motives share similar complexity and that our present conceptions of them are bound by limitations inherent to our measurement instruments.

Multiple motives underlie most participation. A behavior is engaged in to satisfy a number of wants. Variations in the specific motives identified will vary by individual, place, and activity. Over the population, however, the collective package of motives identified in research is most striking in terms of its similarity rather than its difference. The relative ranking assigned specific motives varies, but the constituent motives remain relatively consistent.

What does appear to vary is the intensity and specificity with which motives are identified. Factors such as previous wilderness experience probably help shape more rigorous conceptions of motives as well as produce greater intensity of support for them.

Finally, the motives identified by wilderness participants are often those identified by other types of recreationists. Our ability to distinguish recreationists by motives is limited. It may prove more useful to focus efforts on identifying variations in the intensity with which motives are held and the specificity with which they are defined, perhaps along with clearer articulation of the clusters of motives identified by different wilderness user groups, than in attempting to identify wilderness-specific motives that predict participation.

Decision Making and Participation

Given a certain set of motives, an individual must decide what type of behavior is most likely to fulfill his or her needs. The person can choose recreation, wilderness participation, and a particular environment and set of activities. To understand the forces leading to certain types of behavior and demands for wilderness opportunities, it is necessary to understand the factors influencing the decision process.

Decision Theories.—Early models of choice behavior tended to focus on information processing. Knopf and Driver (1972) and Driver and Brown (1975) adopted a problem-solving approach to recreation choice behavior. Individuals were seen as examining alternatives that would most rationally result in fulfillment of their needs. Thus, a high correspondence between the environment chosen and the need state of the individual was expected.

Haas (1979) examined multiattribute choice models from the consumer choice literature, but ultimately used the expectancy-valence model (Lawler 1973) to examine wilderness preferences. A comprehensive examination of recreationists' decision making has been performed by Krumpe and McLaughlin (1982). They reviewed the literature on choice models, including compensatory models, noncompensatory models, and elimination-by-aspects models, then suggested that recreation choice behavior could be best represented as a constraint-driven, conditional, sequential, elimination-by-attributes model (also see Stankey and McCool 1985).

The model proposed is untested, though McLaughlin and others (1982) did present information that floaters on different river segments vary in their perceptions of the desired attributes of the rivers. Applications of theories of choice have been incomplete. For instance, Cockrell and McLaughlin (1979) were not able to predict choice of a recreation environment using a test of the Fishbein and Ajzen approach (1975). Although not testing the entire Fishbein/Ajzen model, Manfredo (1979) did provide support for a link between basic attitude orientations of wilderness users and their support for various managerial actions. Harris (1982) suggested that different hikers might actually use different decision-making algorithms.

Factors Influencing Decisions.—Many of the factors influencing the decision to participate in wilderness recreation have little to do with wilderness as such. The availability of time, money, or access are all barriers. Many of Krumpe and McLaughlin's (1982) constraining attributes are situational concerns; they assert these will influence the decision to participate before the more positive attributes of an environment will affect choice. One major factor constraining decisions is likely to be the amount of information available to the individual making the choice (Stynes 1982).

Indirectly, data on background characteristics and use patterns of users support these contentions. For instance, wilderness users are predominantly from regions close to the wilderness and a large proportion of use is not for long periods of time (Stankey 1971a; Hendee and others 1978). Thus, constraints of time and distance could serve as barriers to participation.

Social influences exert considerable pressure on the individual. Thus, a person may be influenced by family or friends in the choice of an environment in which to recreate. Knopp and Leatherberry (1982) suggested that collective decision making can influence the information available to an individual choosing to participate. However, Cockrell and McLaughlin (1982) suggested that those most likely to be influenced by social forces are inexperienced participants.

The most common type of group is families, comprising half of all participants, while formal organization members vary from 2 to 10 percent (Hendee and others 1978). Schreyer and Nielson (1978) found that the most common reason river runners gave for going on the trip was that others were already going. Further, allegiance to a group for recreation purposes can be strong. When Schreyer and Downing (1980) asked backcountry visitors to Canyonlands National Park how often they recreated with the persons they were currently with, 46 percent said "frequently."

One factor that can influence the desire to participate is the classification of wilderness itself. Some people have expressed concern that when areas are formally designated as wilderness, they become more visible to the public and are perceived as more desirable as a recreation destination. Becker (1981b) provided indirect support that designations such as Wild or Scenic River increased the perceived desirability of the environment. However, McCool (1985) presented evidence that formal designation of Montana's Rattlesnake Wilderness did little to change participation in the area.

We see participation in wilderness recreation largely as the simple, straightforward desire of people to be in a wilderness. Nevertheless, people might end up in a wilderness because their friends are going, because the area is nearby and easily accessible, or because they simply are not aware of alternative environments in which to recreate.

Attributes and Participation

The previous section concluded that people visit different wilderness environments to fulfill different needs. This suggests that attributes of the environment are important in the decision to participate; they can facilitate or hinder the fulfillment of these needs. Given that such behavior might serve to guide development of an inventory for classifying different recreation environments (Buist and

Hoots 1982), a growing amount of research has examined the attributes of wilderness environments seen as desirable by recreationists.

One earlier attempt to assess attributes important to the wilderness experience was carried out by Peterson (1974b). He had Boundary Waters Canoe Area visitors rate 90 attributes on the desirability of their presence. Undesirable overperformers (things more common than desired) tended to be most commonly identified.

McDonough (1982) found that characteristics of recreation places were important in people's decisions to participate, but that the types of attributes that were important changed with the type of activity. Thus, it was not possible to standardize the aspects of recreation places found important. McLaughlin and others (1982) identified differences in environmental characteristics for six distinct river segments in the Flathead River complex in Montana. They concluded that the segments, though related geographically and used for the same activity (river running), had varying characteristics sought by recreationists for different experiences.

McLaughlin and Paradice (1980) compared the physical, social, and managerial attribute preferences of Idaho cross-country skiers and snowmobilers. They attempted to look at the desired experiences of the users, and concluded that some attributes may be more activity dependent than experience dependent.

The previously discussed motive typology studies have taken user groups and compared them using sets of attributes (Allen 1979). Manfredo (1979) compared his three motive types on 17 groups of attributes and found differences across the types on seven of them. In a somewhat different approach, Haas (1979) used discriminant analysis to see how attributes might predict experience types. He found five resource-attribute-discriminant functions, though the ability of the functions to discriminate among his five experience types was only on the order of 16 to 28 percent.

As an alternative approach to these methods, Watson (1984) employed a microcomputer selection strategy that had people rate desired preferences and then select areas based on the presence of the desired attributes. He wanted to see if a sequential decision process might be modeled through the computer program. Results indicated that in fact there was little correspondence between respondent ratings of attributes for wilderness environments and their subsequent selection of those environments. It is possible that people give more weight to certain attributes in making a decision than they do when rating their desirability individually.

Another approach used by Beaulieu and Schreyer (1982) provided respondents with an open-ended listing of desired attributes, rather than a set list. They compared visitors to mountain and desert wilderness environments, as well as those with differing amounts of experience. Attributes were classed into 16 different categories and ultimately reduced to four—physical, social-psychological, managerial, and activity. Significant differences were noted in the type of attribute and the mix of attributes named by respondents (Beaulieu 1983). Further, a comparison of onsite visitors with persons contacted at home and asked to make a hypothetical decision for participation also showed significant differences in the attributes identified (Beaulieu and Schreyer 1985).

Attribute research has consistently shown differences in preferences across activity, environment, and desired experience. However, there is no standardized list of attributes related to participation. Each study remains an idiosyncratic listing of setting features. Future research needs to be able to identify those attributes most consistently related to the behavior of wilderness recreationists.

Summary

What motivates a person to visit wilderness? Obviously there are many reasons, and they tend to vary among individuals as well as within individuals over time. A person visiting wilderness likely is there for a variety of reasons, many of which might have little to do with the fact that the area is indeed a wilderness.

Motives for visiting wilderness have been measured in many different ways throughout the years, though there has been an increasing movement toward more rigor and generalizability in both measurement and analysis. Motives initiate action; they form the basis for decisions to engage in certain behaviors. As a result, we engage in those behaviors expecting to attain the outcomes that originally motivated them. These expectations form a frame of reference against which we gauge our satisfaction with the experience. They might be more important in determining our enjoyment than actual objective features of the environment.

The most commonly cited reasons for participation in wilderness are solitude and to experience nature. Other reasons commonly mentioned are escape and social experience. It should be noted that none of these reasons is exclusively dependent on a wilderness to be realized. Rather, people perceive wilderness as a good place to attain these outcomes. Specific motives such as escape and social experience do not induce people to visit wilderness as such. They more often tend to come as a consequence of the overall experience.

While many motives are shared, others are not. Further, the relative importance of motives can vary considerably. Variations are a function of the type of activity people engage in, their patterns of participation (length of trip, mode of transportation), the environments they are in, and the background characteristics of the individuals themselves, such as the amount of previous recreation experience they have had. Many other ancillary factors, such as social group influences, proximity to a wilderness, and the formal designation of the area as wilderness, can affect the actual decision to participate.

Recent research has recognized the complexity inherent in motivation by attempting multivariate analyses of visitors' motives. This has resulted in the creation of "types" of wilderness visitors based on combinations of motives. However, these types have generally been idiosyncratic to specific studies.

There has also been an increasing effort to link various motives to preferences for specific attributes in the wilderness environment. This line of research is of growing practical significance in the planning and inventory of oppor-

tunities for different types of desired experiences. Again, this research is in an early stage, and the results of studies often have been difficult to interpret or generalize. However, the complexity inherent in motivation and in preference for various settings represents a challenge that can direct future research.

FACTORS AFFECTING VISITOR BEHAVIOR

Once a person has decided to visit wilderness, many kinds of behavior can be exhibited and many types of experiences obtained. This section is devoted to understanding factors affecting visitors while in wilderness. The first part will examine the psychological response of the individual to the environment and attempt to characterize the nature of the wilderness experience, as well as visitor perceptions of those environments. We then look at factors influencing patterns of participation in wilderness.

The Wilderness Experience

In the last section we talked of attributes of environments as they related to the desire to participate. The individual, however, is not a passive reactor to elements of the environment. Because people bring images and expectations with them, there is the tendency to filter attributes through mental conceptions of wilderness. To understand wilderness behavior, we must be able to view wilderness through the eyes of the visitor (Knopf 1983).

The way a person perceives the environment involves a subjective experience influenced by a collection of individual factors such as cultural and social forces, need state, and life history. Given the complexity of all the factors involved, we can never really know another person's experience; the best we can do is to express, through language, what appear to be shared perceptions.

Such expressions are particularly tentative when referring to environments that contain many symbolic elements of human emotion and values, such as wilderness. Even so, people talk of the wilderness experience as though it were a tangible and widely shared concept. What then constitutes that experience?

The wilderness experience represents a feeling ostensibly unique to wilderness. Essentially, we perceive relatively natural environments, then add cultural and personal meaning (Schreyer 1981).

The values of wilderness have been described in the popular literature by advocates of the concept. Although not empirically based, they represent shared meanings of the purpose of wilderness. Empirical support does exist for these values in more recent literature on motives and psychological outcomes.

Common themes in many popular writings emphasize "nature appreciation, education, freedom, solitude, simplicity, as well as spiritual, esthetic, and mystical dimensions of the wilderness experience" (Hendee and others 1978). Many of the early wilderness advocates echoed particular themes. John Muir wrote heavily of spiritual values (Wolfe 1938), while Robert Marshall characterized esthetic qualities (Marshall 1930). Aldo Leopold supported wilderness as a place to maintain unique recreational opportunities (Leopold 1925), while Sigurd Olson described the wilderness experience as one of insight and personal peace (Olson 1956). Arthur Carhart saw wilderness as a place for mental and moral restoration (Carhart 1955). Wallace Stegner claimed that the wilderness experience helped define our personal consciousness by serving as a frame of reference for our daily lives (ORRRC 1962). Many times, there is no clear distinction between what constitutes a wilderness experience and the values derived from experiencing wilderness.

Tuan (1974) maintained that the wilderness experience derives its meaning strongly from the urban experience: "Attitudes toward wilderness. . . insofar as they are verbalized and known, are sophisticated responses to environment that have their origins in the city. They presuppose the existence and recognition of environmental types and a degree of freedom to choose among them" (p. 248). Kaplan and Talbot (1983) maintained that, while much work has been done on various values associated with wilderness, there has been little research concerning what constitutes the fundamental and distinguishing nature of the wilderness experience. On the other hand, Frissell and Stankey (1972) assumed it would be possible to define a "pristine wilderness experience," a construct including "encountering no other people on a visit, the opportunity to witness completely undisturbed ecosystems, and so forth."

Scott (1974), in reviewing the works of a number of authors, claimed that a sense of "enhanced perception" was a common theme. Similarly, Hammitt (1982) maintained that a major aspect of the wilderness experience is that it affords a particular state of attention in which the individual is not required to attend to elements not considered to be a primary part of the experience. This is facilitated through the concept of "solitude" or "privacy" (Hammitt and Brown 1984); social expectations for interaction may be one of the strongest forces for distraction.

It is likely there is no such thing as **the** wilderness experience in terms of objective criteria. Knopf (1983) pointed out the many ways in which people can experience the same environment depending on their frame of reference. A given campsite can be seen as being either too secluded or too crowded depending on the expectations of the visitor (Foster and Jackson 1979). If visitors are seeking different types of experiences, they will likely feel differently about what they encounter.

Further, perception of the environment can be affected by the extent of differentiation a person makes. Some might see one wilderness as similar to another, while others obtain different feelings in different life zones or drainages in the same wilderness. How does the formal designation of wilderness affect the type of experience a person is likely to gain there? Would the same state of mind exist if the area were merely an unclassified roadless area (Schreyer 1980; Knopf 1983)? Reed (1973) showed that people's affective responses to hypothetical environments differed depending on whether they were labeled "National Park," "National Forest," or "State Park."

A major influence on perception is previous experience. A person might feel more affiliation with an environment through previous experience (Tuan 1974; Williams 1980),

and evaluate the environment through many more subjective and symbolic values. Visitors to a new environment might evaluate what they encounter as normal (Heberlein 1977), while those who are experienced will evaluate the same scene in the context of what they have experienced before (Schreyer and others 1976; Nielsen and others 1977).

Images that people possess of an environment, whether experienced personally or not, will affect their behavior and perceptions in the environment (Knopf 1983). Such images often have little to do with objective reality (Hunt 1975). Rather, they are subject to shaping through marketing or through cultural myths and values (Lee 1972; Schreyer and Roggenbuck 1980). It is apparent that the experience of wilderness is likely to be highly personalized. Thus, much of the discussion of wilderness focuses on the individual's subjective state.

Wilderness Experience as Subjective State

Characterizing Subjectivity.—In essence, the wilderness experience can be characterized as whatever we are experiencing when we feel we are in wilderness; as such, it is not subject to objective measurement. Further, Knopf (1983) suggested that the way in which we conceptualize such environments is colored by our disciplinary backgrounds (for example, psychology, sociology, or resource management).

This need not constrain us from understanding the nature of things experienced. Given there is no absolute definition, it becomes a challenge to characterize the dimensions or features people use to describe what they feel.

Roderick Nash has been a consistent proponent of the fact that wilderness is "all in your mind" (1982). This emphasis has, in fact, been a strong underpinning to the notion that one does not have to visit wilderness to experience it. "Knowledge value" of wilderness suggests the experience goes beyond the bounds of the legally defined area.

This subjective meaning of wilderness is tied not just to the environment itself, but also to the context within which we define it. According to Tuan (1974, p. 112): "By the time we can speak of preserving and protecting wilderness, it has already lost much of its meaning. . . . 'Wilderness' is now a symbol of the orderly processes of nature. As a state of mind, true wilderness exists only in the great sprawling cities."

A wilderness experience depends on the person's perception of an environment. Thus, researchers have increasingly involved cognitive psychology to describe responses to environments. Kaplan (1977) described two basic types of attention, voluntary and involuntary. Many of the attractions of natural environments appear to be those that focus strongly on involuntary attention, capturing the attention of the individual with little effort or notice (Driver and Greene 1977). Attractions that fascinate or arouse us involuntarily fall into this category.

Voluntary attention, on the other hand, is much more active. This can be demanding and result in a need to return to a more casual and passive involuntary state. Hammitt (1982) claimed that wilderness solitude represents pursuit of a state of involuntary attention. However, a key is that the person controls the conditions under which that involuntary attention is exercised; one does not have to worry about the necessity to respond to a series of unrelated demands, such as social pressure. Hammitt (1984) maintained that this ability to attend to what one wants reduces the "cognitive cost" to humans, performing a restorative function for the individual. In research on the perceived values of wilderness environments, he reported that two elements seen as being particularly important were "resting the mind from anxiety and mental fatigue," and "promoting a sense of tranquility and peacefulness."

Subjective experiences are also characterized by emotion or effect. Many descriptions of wilderness experiences are characterized by altered states of mind in which strong emotions are felt. For instance, Scott (1974) described an "illusion" experienced by George Catlin through concentrating on a map of North America, in which he saw himself floating over the continent and witnessing the destruction of the bison. The emotional impact of this experience resulted in his vision of creating National Parks. According to Scott, "The episode can be described as a self-induced altered state of consciousness characterized by depersonalization, hallucinations, altered time sense, an intense feeling state, oceanic yet simultaneously detailed perception of environmental wholeness, intuitive intellectual insight, and a resultant prophetic proposal."

Thus, the wilderness experience has cognitive and affective components that interact to produce the experience. Ulrich (1983) developed a model of the relationship of effect to perception. He asserted that a person's initial effective state will influence the perception of the natural environment, and that the effective reaction to that environment will affect cognition or interpretation of what is seen, degree of sensory arousal, and future behavior. In some cases, this effect can serve to intensify and enhance the experience for the individual, and can be translated into action. According to Ulrich, "A wilderness backpacker who is fatigued might feel exhilaration or elation upon viewing an aesthetically spectacular setting, and these effects would produce physiological arousal and help to sustain his journey" (Ulrich 1983, p. 94).

Such states of restoration, effect, and arousal appear to help the individual attain higher states of awareness or self-consciousness (Scott 1974; Young and Crandall 1984) and improve the likelihood of attaining Maslow's (1968) level of "self-actualization," in which the person achieves a sense of personal fulfillment at the maximum level of human performance. The process of self-actualization is often characterized by "peak experiences," defined as situations in which the individual becomes egoless, where space and time become relatively insignificant, and the person's identity becomes merged with action and attainment of a greater sense of the whole environment.

Scott (1974) claimed that the most prominent wilderness writers, such as Muir, Catlin, Thoreau, and Leopold, used terminology closely linked to these concepts. He suggested that wilderness environments catalyzed their personal self-actualization. In making the argument that such environments promoted self-actualization, he cautioned against assuming that **only** such environments or experiences did

so. Rather, he was claiming, much like Hammitt (1984), that such environments were particularly rich in characteristics that foster such states. The wilderness experience can promote altered states of consciousness and awareness, but it shares this quality with other forms of human experience, such as art and religion.

In perhaps the only empirical test of such relationships, Young and Crandall (1984) concluded that wilderness users were more self-actualized than nonusers. Frequent wilderness users, however, were no more self-actualized than nonfrequent users, and the strength of the relationship between wilderness use and self-actualization was concluded to be weak.

The Religious/Spiritual Experience.—When focus moves toward altered states of consciousness and extreme conditions of effect, wilderness experiences appear similar to mystical, spiritual, or religious types of experiences. This is strongly rooted in the philosophical writing about nature by early wilderness advocates, and the linking of nature with the transcendental experience by writers such as Thoreau.

John Muir considered "wild nature" the conductor of divinity, and believed that wilderness should exist as a source of free-flowing psychic and spiritual energy (Nash 1982). Arthur Carhart (1920, p. 20) felt that "the individual with any soul cannot live long in the presence of towering mountains or sweeping plains without getting a little of the high moral standards of nature infused into his being." Joseph Wood Krutch (1958, p. 275) stated, "Wilderness and the idea of wilderness is one of the permanent homes of the human spirit." Roggenbuck and others (1973) used the philosophy of Sigurd Olson to express the long-term notion of spiritual impact of the wilderness experience:

> They think they go into the back country for a lark, just to test themselves or to face a challenge, but what they really go for is to experience the spiritual values of wilderness.... It may take years for them to realize what they found, but sooner or later it will come back to them.... (Olson 1969, p. 137)

Much of the writing moves from the concept of the experience of wilderness itself to suggestions that the natural environment should be used as a source of inspiration for the development of human ethics (Churchill 1982; Douglas 1983). This belief has led to study of different religious or value systems such as Native American cultures (Callicott 1982; Erickson 1977), or Asian religions, such as Taoism (Ip 1983), Jainism, Buddhism, and Hinduism (Nash 1982), that are compatible with respect for nature. Tuan (1974) warned that any culture's stated ethos does not necessarily represent their actual behaviors toward the environment; many cultures espousing unified views of humans and nature nevertheless have participated in major environmental depredations.

Although most writings have been in the domain of the philosophical, there have been some attempts to take a more systematic look at the spiritual aspects of the wilderness experience. Scott (1974) used a framework of altered states of consciousness designed by Fischer (1971) to analyze the nature of the experience being described by the nature writers. Using this framework, Scott noted:

> ...the reverie of Catlin is a meditative state mediated by the parasympathetic component of the autonomic nervous system and the treetop adventure of Muir would be an ecstatic state resulting from stimulation of the sympathetic division of this system. Carl Jung...conceptualized self-development or "process of individuation" in much the same way as Maslow and used the term "archetype" to describe man's inherited unconscious complex of feelings, ideas and images. Jung personally received tremendous inspiration from nature and mountains and perceived in the latter an expression of man's potential. Wilderness experiences may involve the expression and reaffirmation of specific archetypes. (Scott 1974, p. 236)

Spirituality can encompass a broad range of human experiences. Some of this spirituality has been viewed in the context of a religious experience. Perhaps the most detailed analysis of the religious content in wilderness is Graber's monograph (1976). This work is more speculative than empirical, but it attempts to bridge the gap between religious and wilderness values. She noted that religious experience does not have "content," but rather is characterized by the subjective nature of human feelings toward certain objects, institutions, or ideas. Wilderness is essentially "sacred space," an environment toward which religious feelings are directed. Graber used the notion of "geopiety" to represent a broader feeling of "reverence, propitiation, affection and compassion" (Graber 1976, p. 5) directed toward the earth. In this sense, many religious feelings directed toward wilderness are really manifestations of broader ethical feelings about one's relationships with nature, in much the same way that a specific church is the vehicle for experiencing one's feelings about Christianity.

Graber drew analogies between wilderness purists and religious sects. Both represent a social order in which there is an accepted rhetoric and mode of behavior to reinforce the validity of the belief system. The imagery and content of the revered writers serve to direct one's perceptions in wilderness, so that one is attuned to seeing the "right" things, and thus becomes appropriately socialized to being able to have the religious experience of wilderness.

Graber asserted that religious connotations are hard to escape, even when segregated from one's personal religious feelings:

> The wilderness ethic is strongly religious in character. Wilderness is treated as sacred space by the community of purists, whether or not purists consciously accept the notion of wilderness as hierophany. (Edward) Abbey considers himself an atheist, Krutch was an agnostic, at one time (Ansel) Adams denied or apologized for the spiritual quality of his photographs; yet none of these artists can quite escape his own preoccupation with sacred power. If one believes that wilderness is a manifestation of sacred power...he gains a fixed point, or center, which stands out from the chaotic relativity of ordinary life. (Graber 1976, p. 11)

Graber argued that wilderness provides a source for religious experience because it is a focal point for human needs for order, for community, and for a unified image that can provide meaning. She asserted that the force of this feeling is catalyzed into political action by those affected. Much of this energy "stems from the ability of wilderness imagery to flow into the void left by the erosion of spiritual and aesthetic values associated with the countryside and city" (Graber 1976, p. 115). Whatever the mobilizing forces, it is apparent that because people perceive wilderness as an appropriate focus for the expression of religious feeling, this becomes part of a broader litany through which persons may learn to experience values that religions traditionally deliver: meaning, order, transcendence, communion.

Perceptions of Environments

Much of the previous section has dealt with the effective content of the wilderness experience. This section will focus more on the cognitive elements of wilderness: what people actually perceive as the object of the wilderness experience, and how that is given meaning in the mind. This will influence the set of attitudes people hold about wilderness.

Wilderness Purism.—It is virtually impossible to tap the full range of personal meanings of wilderness. Because it is subjective, many idiosyncratic components of knowledge and feeling will be involved. However, it may be possible to create some summary that may reflect these broad concepts. This has led to the attempt to develop attitude scales tapping people's concepts of wilderness.

The first effort to represent empirically the range of wilderness visitor attitudes was made in the Pacific Northwest by Hendee and others (1968). They created a set of 60 questions consisting of 20 items on liked or disliked features of wilderness, 20 on activities that might occur in wilderness, and 20 on benefits that might be obtained. Respondents were to rate the items on a scale from "strongly dislike" to "strongly favor." Persons who were at the purist end of the scale in terms of more extreme scores were labeled "wildernists," while those at the other end were labeled "urbanists" (Hendee and others 1968).

Responses to the scale were factor analyzed to explore the underlying dimensions of wilderness attitude. Of course, the selection of items in part predetermined the content and nature of the dimensions. They identified seven different dimensions of wilderness attitude: spartanism—the physical desire to encounter the environment in a challenging manner, antiartifactualism—the appreciation of the lack of signs of human development or activity, primevalism—the desire to experience a natural setting, humility, outdoorsmanship, aversion to social interaction, and escapism. Using the degree of association of items in the factors as a guide, a refined scale was then developed using only 30 of the items. This refined scale was subsequently used to compare wilderness users' perceptions toward appropriate behaviors and toward possible management strategies, and their background characteristics. They found wilderness purists to be young, highly educated, and predominantly from urban backgrounds, lending support to the notion that wilderness appreciation arises from an urban culture.

This concept of tapping the wilderness-attitude domain has been criticized as having somewhat questionable validity. There is the feeling that what is being measured is limited to the domain of the 30 items, which may be a very narrow expression of people's attitudes toward the wilderness experience (Copp 1967). Heberlein (1973) noted that any attempt to measure attitudes should recognize both the effect and belief components of attitudes. Further, there is a need to understand that attitudes are linked and interwoven in a complex manner. One must be able to account for the centrality of the attitude toward the object being studied and the relationship among the attitudes. Heberlein asserted that failure to consider these factors in the conceptualization of such an attitude scale limits the practical utility of its application.

Stankey (1971b) used a somewhat different approach to the measurement of wilderness attitude. He attempted to link the scale to the Wilderness Act with the rationale that because that legislation served as a constraint on, as well as a guide to, management of wilderness, attitudes should be defined in the context of the act. His scale consisted of 10 statements concerning three aspects of wilderness defined in the act: ecology, level of development, and simplicity of recreational activities. Four other items relating to the nature of the wilderness environment were also added. Respondents rated each item in terms of favorability on a five-point scale ranging from very desirable to very undesirable.

Persons were scored according to their answers ranging from 14 to a possible 70 points. Persons at the high end of the scale were labeled "strong purists" while those at the other end were "nonpurists." Stankey used this classification to examine differences in user perceptions of encounters with others (Stankey 1973). He argued that because purists were closest to the conception of wilderness held in the legislation governing these lands, managerial decisions about limiting use and protecting the environment should be geared toward the attitudes of persons who were closest to the spirit and intent of the legislation (Stankey 1972).

Wilderness purism scales have not achieved widespread utilization. Applications of the results from such scales might be hindered by the notion of "purist," which carries with it elitist connotations that run counter to more democratic notions of management. Schreyer and others (1976) developed a wildernism scale based on Stankey's approach. They developed an initial scale of 27 items and then used 17 to classify river floaters in Dinosaur National Monument. In order to avoid the potential semantic contamination of the purist label, persons scoring high on the scale were called "high wildernists." Differences in wildernism scores were linked to significant differences in visitor characteristics, motives for the trip, trip characteristics, perceptions of crowding, and evaluations of management strategies.

Rentz and Schreyer (1977) developed a multi-item "attitudes toward wilderness" construct in a study of wilderness hazard perception. They found that although the scale was positively related to previous exposure to general information about hazards, it was not related to

perceptions of hazards independently. In a similar study, Williams and others (1984) found that prowilderness attitudes did relate to greater preparation and awareness of hazards among cross-country skiers.

Wilderness Attitudes and Perceptions.—Although it is difficult to tap the full domain of attitudes toward wilderness, it is much easier to identify specific attitudes and perceptions. One approach has been to ask people what elements characterize wilderness. A public opinion survey to test general public awareness of wilderness (Yankelovich, Skelly, and White, Inc. 1978) asked people what activities they felt were or were not permitted in wilderness. They did not define wilderness or make reference to legally designated areas, leaving that to the interpretation of the respondent.

Over half the public believed developed campgrounds with sanitary facilities were permitted, 42 percent believed sightseeing by car was permitted, 41 percent thought commercial harvesting of trees was permitted, and 32 percent thought motorcycling and jeeping were permitted. Although people might be disturbingly unclear about the exact properties of wilderness, it is notable that they have strong positive feelings for the concept. Eighty-three percent of the sample believed that the Federal Government has an obligation to save large areas of undeveloped land for wilderness preservation.

In an attempt to assess visitor perceptions of wilderness qualities, Schreyer and Nielson (1978) asked river floaters in Desolation and Westwater Canyons in Utah if they felt they had been in a wilderness while on the trip. Eighty percent of the sample indicated in the affirmative. Respondents were then asked when they felt the wilderness began (neither river is formally designated in wilderness status). For Desolation Canyon, nearly a third indicated it started while riding to the launch site, while another 15 percent indicated it started at the launch site.

Another approach has been to ask persons to describe what characterizes a particular environment for them. In a public opinion poll about attitudes toward the California Desert (not legal wilderness), the Field Research Corporation (1977) found that 62 percent of the respondents indicated beauty and nature, 54 percent said solitude, 42 percent identified freedom, and 34 percent said adventure. Beaulieu (1984) used an open-ended format to ask people for aspects of a wilderness environment that led to their desire to participate there. The largest proportion of respondents identified aspects of the psychological experience as most important. About 45 percent of respondents identified these elements, while only about a quarter of the respondents identified actual physical components of the environment.

Lucas (1964b) asked visitors to the Quetico-Superior area of Ontario and Minnesota about their perceptions of wilderness qualities, the area considered wilderness, and appropriate uses. Although there were substantial variations in response, most visitors had well-defined notions of what constitutes wilderness. Approximately three-fourths of the canoeists sampled identified wilderness qualities as a major reason for visiting the area (Lucas 1964a).

In assessing preferences of the public for wilderness conditions, Peterson and Lime (1973) cautioned against potential measurement bias. They provided evidence that nonresponse bias can affect the validity of data, and suggested that persons answering questions in the field might answer differently from persons answering at home. Beaulieu and Schreyer (1985), in a study of wilderness attribute preferences of persons onsite versus those at home, also found significant differences in response patterns.

One of the major components in the perception of wilderness qualities is the more general idea of the esthetics of natural environments. There is a vast literature on this subject that has been organized and reviewed elsewhere (Daniel and Vining 1983; Ulrich 1983). Worth noting, however, is an increasing tendency to move from evaluations of general landscape features to specific components of the environment, such as air quality (Daniel 1979) and the impact of sound on the experience (Kariel 1980; Anderson and others 1982). An important aspect of esthetic qualities is the extent to which they can be used to establish the value of a particular area. In this regard, Leopold (1969) used esthetic elements to characterize Hell's Canyon on the Snake River as a unique environment.

Perception and Satisfaction.—How do people evaluate wilderness? What makes them satisfied or dissatisfied with what they encounter? Because wilderness is a resource judged by subjective criteria, sources of satisfaction and dissatisfaction provide insights into what comprises the most appropriate definition of wilderness. Sources of dissatisfaction can provide managers with feedback indicating the extent to which they are providing desired wilderness conditions.

While it makes sense to measure satisfaction, research efforts to do so have not been highly successful. Global measures of satisfaction are often used, but these provide little in the way of useful information about a person's response to the many varied and complex aspects of the recreation environment (Probst and Lime 1982). Thus, there has been an increasing tendency to measure various aspects of satisfaction. For instance, Ditton (1979) used nine different statements related to satisfaction in surveying Buffalo River floaters.

Studies have looked at specific elements contributing to overall satisfaction, such as mode of travel (Shelby 1980a). Lucas (1980) looked at the degree of association between a number of elements of the trip and overall satisfaction for wilderness hikers, while Shelby and Nielsen (1975) did the same for river floaters. Peterson (1974b) used a similar though more detailed approach to evaluating sources of wilderness quality through the discrepancy between desired and actually encountered conditions. Other approaches to the subject have included measuring changes in the behavior of users in response to perceived conditions (Anderson 1980).

Because motives represent reasons why people visit wilderness, it stands to reason they would be related to satisfaction with conditions encountered. The importance of the motive is thus critical; if high, then we would anticipate a close correlation between the extent to which that motive is satisfied and the actual use conditions that foster its realization. If the motive, say solitude, is of low value, however, there might be little dissatisfaction with high levels of encounters (Stankey and McCool 1984).

McCool and Petersen (1982) linked types of sources of satisfaction and dissatisfaction to respondents' scores on various desired psychological outcomes. They argued, following Herzberg's (1976) two-factor theory of satisfaction, that separate conditions might produce satisfaction and dissatisfaction and that a condition whose presence leads to satisfaction might not result in dissatisfaction when absent; conversely, conditions producing dissatisfaction do not necessarily lead to satisfaction if absent.

One of the most important concerns addressed by this research is what factors are most important in contributing to visitor dissatisfaction. One of the most important sources of dissatisfaction—encounters with others—will be dealt with subsequently. Many other sources of dissatisfaction in wilderness are related to perceptions of impacts resulting from human use (Bultena and others 1981a). Studies generally focus on different dimensions of impacts. For instance, Lucas (1979) examined various environmental factors in three wilderness environments. Litter turned out to be the most commonly perceived negative impact.

McCool and Petersen's (1982) work on the two-factor notion found that some aspects of the environment served to act as satisfiers, enhancing the experience, while others were seen as dissatisfiers, detracting from the experience. The most commonly perceived dissatisfiers were related to encountering others. Other negative factors were litter (identified by 57 percent of respondents), insects (47 percent), and dogs (35 percent).

Some studies have looked at specific negative aspects. In a study of dispersed forest recreationists, Downing and Clark (1979) showed that 92 percent of managers felt litter was a serious problem, compared to 50 percent of visitors, though both identified it as their most commonly perceived problem. Ninety-one percent of managers felt vandalism was a serious problem, compared to only 37 percent of the visitors.

In a river setting, Shelby and Nielsen (1975) found that perceptions of use-related impacts correlated significantly with overall trip satisfaction on the Colorado River in the Grand Canyon. In a less pristine setting on the Upper Delaware River in New York, Dawson and others (1981, 1982) also found litter to be the most commonly perceived problem, though only 23 percent of their respondents listed it as a serious problem. In a study of Boundary Waters Canoe Area Wilderness canoeists, Anderson (1980) examined "negatively valued attributes" perceived at entry points and campsites as well as during the day one entered the wilderness. Seeing litter, having to camp at heavily used campsites, and seeing peeled bark on trees were among the most negative of perceived attributes.

As part of the National River Recreation Study, recreationists were asked to evaluate a comprehensive list of perceived problems (Knopf 1982). The most common problem was again litter, with 54 percent of all respondents across 38 different rivers indicating that it was at least a slight problem.

One concern about impact is the extent to which it might be changing. Lucas (1980) asked repeat visitors to nine wilderness areas whether conditions were getting better, worse, or were about the same. While roughly half the respondents indicated things were about the same, the proportion of persons who identified conditions as getting worse ranged from 20 to 37 percent.

Evaluations of impact can vary depending on the nature of the individual. For instance, Vaske and others (1980) showed that persons who had first visited an environment several years before tended to evaluate environmental conditions more negatively than those whose first visit occurred recently. Anderson (1980) showed differences in evaluations of impact across the four motive-profile types she created for the Boundary Waters.

Two major observations emerge from this research. First, visitor dissatisfaction may result as much from differences in individuals as it does from differences in the objective conditions in the environment. Variations in motivations and previous experience are significant influences on evaluations.

Second, the most commonly cited sources of dissatisfaction have to do with the presence of others or their perceived impacts. Litter is probably the single greatest negative factor encountered in a wilderness setting.

Influence of Information on Participation Patterns

To this point, we have examined factors that influence visitor attitudes, perceptions, and behaviors. Although many of these factors are inherent in the individual or the environment, others are a function of management. Managers often desire to influence visitor behaviors or perceptions, in order to maintain the quality of the environment or reduce problems causing visitor dissatisfaction.

One of the more common techniques for influencing visitor behavior is using information to aid visitors' decisions about such things as trails to hike or campsites to use. This can have a positive effect on the persons involved because they are more likely to find a place meeting their expectations. Further, it can serve as a management tool in helping to distribute use away from heavily impacted areas.

The distribution of information has been tied to other management strategies, such as the requirement for permits (Lime and Buchman 1974). Such permits can be a source of information that can be fed back to the visitor about use patterns and rates. Further, issuing a permit can serve as a source of contact with agency personnel, and an opportunity to give visitors information that might help disperse use (Magill 1974).

A growing body of research has developed from attempts to influence visitor behavior through the use of information. Although some successes have been noted, results are mixed, suggesting more sophisticated methods may be necessary. The primary focus of information research has been on redistributing use from heavily used sites to less impacted areas.

Use Distribution.—Schomaker (1975) found that information on "crowded areas" in Colorado's Rawah Wilderness handed out at the trailhead had no significant effect on travel route selection. A similar attempt to redistribute use through rules printed on required permits in the Great Gulf Wilderness of New Hampshire (Canon and others 1979) also failed to obtain significant results. Lucas (1981) attempted to redistribute use in the Selway-Bitterroot Wilderness through the use of brochures providing information on use levels of trails. Overall use patterns were not shifted toward lightly used trails. Such results have

been blamed on information being given to visitors after the decision to use an area had already been made, suggesting that such information needs to be available earlier in the decision process.

In the Boundary Waters Canoe Area, persons with permits for heavily used entry points in 1974 were sent information packets before the 1975 season, providing information on use levels and alternative routes. Results showed about one-third of the respondents claimed the information influenced their travel plans for 1975 (Lime and Lucas 1977). Krumpe (1979) and Krumpe and Brown (1982) employed an experimental design in Yellowstone National Park to influence trail selection by providing persons with information about characteristics of various trails based on visitors' desired experiences. They found that 37 percent of the subjects selected one of the targeted trails. Hahn (1982) used a photographic decision-tree approach with visitors to the San Rafael Swell region of Utah before they made actual travel plans. She found that about a quarter of those who returned to the Swell actually used new areas targeted in the process.

Increasingly, research has attempted to do more than just give information to recreationists. One approach is to test the relative effect of different media for communication. Roggenbuck and Berrier (1981, 1982) tested the value of two different information media to distribute camping use in North Carolina's Shining Rock Wilderness. They used a brochure alone and in combination with a personal message. Both approaches resulted in redistribution of use, but neither was more effective than the other.

Appropriate Behaviors.—In addition to distributing use, information can affect the behavior of wilderness visitors. Because impact is a particular concern, development of behaviors likely to minimize impacts is a desirable goal. This can depend on previous learning on the part of the individual, or it may be a function of conscious efforts to give such information to visitors in a way likely to produce the desired behavior.

Fazio (1979a) suggested that a mandatory permit is a successful way to deliver information to wilderness visitors. There is the question as to which type of communication is most effective. In a test of backcountry hikers in Rocky Mountain National Park, Fazio and Gilbert (1974) used a brochure, slide show, and trailhead sign to inform hikers of appropriate behaviors. Only the slide show resulted in significant improvement in low-impact camping knowledge.

Different media can be more or less useful in getting to the visitor. In a study of Selway-Bitterroot visitors, Fazio (1979b) reported that the most commonly reported sources of information concerning appropriate behaviors were the Forest Service, "experience," and friends and relatives. McCool and Haydock (1976) found that the most common sources of information on safety behavior among Zion Narrows hikers were park rangers and warning signs.

Although it might be possible to identify sources of information, it is not clear just how effective they are. In a study of cross-country skiers in the Wasatch Mountains of Utah, Williams and others (1984) found that only 48 percent of skiers reported ever seeking out any information on avalanche hazards, and only 17 percent had sought out information on the day of their outing. Rentz and Schreyer (1977) underscored the importance of previous learning in showing that there was an **inverse** relationship between exposure to park information and preparation for natural hazards in Arches and Canyonlands National Parks.

To maximize effectiveness, some have attempted multimedia approaches. For instance, Matheny (1979) reported an attempt to reduce trail shortcutting through the use of signing, local school poster contests, and the use of mass media. The program, combined with experimental revegetation, was considered a success.

In recognition of the need to become more sophisticated in reaching audiences, researchers have adopted notions of "market segmentation." This approach is geared toward identifying persons most likely to be a source of concern, studying their characteristics, and then targeting information strategies directly toward them. For instance, Matheny (1979) identified 13- to 17-year-olds as the group most likely to engage in shortcutting. Consequently, special school education programs were targeted toward them. Robertson (1982) found several factors significantly related to appropriate behavior in wilderness, including knowledge of behaviors, attitude, education, and age. Fazio (1979b) reported on studies of the knowledge of wilderness users in Rocky Mountain National Park and the Selway-Bitterroot Wilderness. He found cross-country hikers and technical climbers to be more knowledgeable than day hikers in Rocky Mountain National Park. In the Selway-Bitterroot he found outfitters and group leaders to be more knowledgeable than hunters, day users, pilots, or horse campers. Thus, if one wants to be effective in reaching people, it might be useful to attempt to reach persons with the least amount of knowledge.

Role of Education in Influencing Behavior

Information can be seen as a passive way of influencing behavior, while education is a more active approach. There is a belief that education will not only create a greater appreciation of wilderness, but will increase demand for such environments (Hendee and Roggenbuck 1984). A more common notion of wilderness education is the use of a field experience in which the individual confronts the forces of nature. Such programs, often described as "high adventure" or Outward Bound types of experiences, are deemed to have long-term beneficial effects on the individual, not only in terms of appreciation of the wilderness environment, but in the self-concept that has benefited from challenging nature.

Many studies have been performed on these types of programs, and the literature has been summarized elsewhere (Meier and others 1980; Kaplan and Talbot 1983; Kaplan 1984). Although much attention has been directed to this topic, results are not particularly straightforward. A number of studies describe both immediate and long-term changes in participants (Thorstenson and Heaps 1973; Heaps and Thorstenson 1974; Kaplan 1974; Thorstenson and others 1975). Other studies are less positive. Gillette (1979), in a study of attitude changes

resulting from participation in an Outward Bound program, found significant changes in only 15 percent of the items measured. In a test of potential changes in anxiety levels of participants in both an adventure program and in a leadership experience, Chesnutt (1982) found neither long- nor short-term changes.

It appears that approaches to this line of research will have to be more standardized and systematic to establish generalizable conclusions concerning the effects of such programs. Programs differ significantly in clientele, course content, duration, and intensity. Measures vary from attitudes to personality dimensions to actual behaviors. In this sense, it is often difficult to know who is doing what to whom.

Social Influences on Behavior

Any attempt to understand the nature of human behavior in a wilderness setting must account for social influences on behavior. Because most visitors enter wilderness in groups (Cheek and others 1976; Lee 1977), the wilderness visitor is enmeshed in a social context that strongly defines the recreation experience (Cheek and Burch 1976; Knopf 1983).

Social groups have been identified as a major influence on recreation participation (Field and O'Leary 1973; Field and Cheek 1974; Hammitt and McDonald 1982). Such social considerations might be more important in predicting behavior than the activity, as that behavior might be keyed to the group dynamics of the situation (O'Leary and others 1974; Field 1976). Participation can be the result of the desirability of social interaction itself. Social learning can affect people's preferences for participation, as evidenced by the influence of activities learned as a child on adult preferences (Yoesting and Burkhead 1973). Hendee and others (1968) found that nearly 70 percent of wilderness users made their first visit to a wilderness before the age of 15. Further, indirect factors such as stage in the family life cycle can affect preferences for different types of activities. For instance, Burch (1966) found that remote-camping families were most likely to be those just starting a family or older families in which the children were leaving home.

Many social forces are at work to influence an individual. Cockrell and McLaughlin (1982) outlined ways in which social influences operate on wild river recreationists. They suggested that such forces shape beliefs about the desirability of various activities, the motives for participation, and through direct social influence on participation. Social group influences can be an important force in shaping members' behaviors (Sessoms and Stevenson 1981). Further, the mechanics of the group composition, such as party size (Lime 1972), can affect behavior patterns.

As a part of a specific cultural group or lifestyle, individuals identify certain activities or behaviors as being appropriate to demonstrate that lifestyle. Thus, rates of visitation to National Parks are generally higher among middle class communities than working class communities (Bultena and Field 1978, 1980). In many cases, recreational activities are seen as defining the lifestyle, and unique "social worlds" can evolve (Devall 1976).

Persons acting in a group have a notion of appropriate behavior within the group. Such social roles might be specific to a given situation. However, Burch (1965) suggested that activities carried out in forest settings show considerable overlap to roles played out in daily life. To the extent that people feel certain behaviors are appropriate, they are responding to shared norms of the group.

Such norms might be global perspectives on how lands such as wilderness should be managed or used. In their study of wilderness users in the Pacific Northwest, Hendee and others (1968) identified five clusters of norms about appropriate behaviors shared by visitors: responsibility and equity, rejection of controls on behavior, withdrawal from the symbols of civilization, maintenance of unpolluted campsites, and camping skills. This survey was conducted at the beginning of the environmental movement; given that use pressures and controls have shifted dramatically since, it would be interesting to see whether a replication would yield the same dimensions of norms.

In his study of wilderness "purism," Stankey (1971b) used measures of visitors' attitudes on levels and types of use of the wilderness, as well as preferences for management alternatives. These values became the rhetoric of purism. Graber (1976) asserted that "wilderness purists" have a definite "ethic" of behaviors that should be exhibited. In a sense, this defines membership in the class of purists. One identifies oneself not just by one's attitudes, but by one's behaviors.

Social forces can affect the meaning of a given place, determining the behaviors judged appropriate within the environment. Lee (1972) suggested that a major factor influencing behaviors in remote settings is the image of the place shared by social groups and their conceptions of appropriate behaviors keyed to that definition. Schreyer and Roggenbuck (1980) suggested that shared meanings of places can be global and affect specific behaviors only in a very general sense. In support of this notion, Schreyer and White (1979) showed that park visitors' definitions of the meaning and purpose of National Parks were unrelated to their evaluations of the appropriateness of certain nontraditional recreation activities. Rather, evaluations were more linked to an individual's participation in the activity; if he or she participated in the activity, he or she was more likely to consider it appropriate.

Social forces can also affect a person's perception of the experience itself. It is possible that group sentiments reinforce individual evaluations of satisfaction, in a sort of "aren't we having a good time!" fashion. Lime (1977) suggested that persons with considerable experience, such as commercial outfitters on whitewater float trips, can exert considerable influence over the experience for visitors. Influence can range from enhancing visitor perception through interpretation to increasing visitor arousal by creating illusions (for example, that rapids are larger and more dangerous than they really are).

Evolution in Behavior

The forces influencing wilderness behavior are dynamic. As a result, the notions of what constitutes appropriate behaviors also evolve. Some of this evolution is in response to use pressure. For instance, the norm in rock

climbing has moved to "clean" climbing rather than traditional methods such as the use of pitons and other more permanently defacing techniques. Technology has had an impact as well. Lightweight, portable cooking sources are not only common, but in many cases required. The traditional wilderness experience of cutting pine branches for one's bed and sitting around a large campfire in the evening has been replaced with minimum-impact camping techniques. Even where such behaviors are not required by agency personnel, they can become part of a norm used to assess the legitimacy of an individual's presence in wilderness.

The evolution of technologies has led to controversy over the extent to which certain activities are appropriate. For example, are hang-gliders appropriate in wilderness? It can be argued that few activities are closer to representing harmony between user and environment. Does the technology involved represent the trappings of civilization any more than a lightweight backpack or tent? Is the visual intrusion any more offensive than the sound and contrails of a 747 passing overhead? Such questions force us to confront both the perceptual and legal conceptions of what really represents wilderness; continual evolution of technologies is likely to continue, particularly if there is a market supporting research and product development (White and others 1980).

There has also been an evolution in the nature of experiences sought in wilderness. A growing number of persons are using such environments to actively seek risk (Schreyer and others 1978). Wilderness environments can be very challenging, and persons seeking to experience risk find them attractive for such encounters. Many reasons have been advanced for why people seek to put themselves at risk. They range from stress-seeking personalities (Klausner 1968) to physiological chemistry of the brain (Zuckerman and others 1972) to neurotic death wishes. Schreyer and White (1979) suggested that risk involves a situation in which a person gains immediate feedback about performance and is required to behave in a way that requires optimal use of skills and abilities. This leads to feelings of self-determination, achievement, and a sense of perceptual focusing on the activity, resulting in a greater sense of awareness and heightened personal insight.

Summary

Wilderness is an objective reality composed of physical objects in the environment. What makes those objects "wilderness," however, depends on our personal feeling about such environments. In this sense, it is a very subjective concept. Our image of wilderness is likely influenced by our values, beliefs, emotions, previous experiences, exposure to information, social influences, and even our fantasies. These subjective images affect what we consider wilderness, whether we decide to visit it, and what we experience when we are actually there.

Public perception of wilderness is very positive when the general population has been surveyed. There is tremendous variation, however, in what people actually consider wilderness to be. People also vary strongly in their intensity of feelings toward the value of wilderness. This range of intensity has been measured by various researchers as "wilderness purism" or "wildernism." Such value systems have been linked to attitudes toward wilderness preservation, management, and appropriate behaviors while in wilderness.

The frame of reference people carry into the wilderness affects their perception of and experience in wilderness. While anyone can have some kind of experience in environments labeled as wilderness, much research has focused on "the wilderness experience" itself. This wilderness experience does appear to be tangible and valid, but it is very idiosyncratic, and depends on individual needs and images. There is more to it, however, than just saying "people are different." There are, in fact, commonalities underlying the idiosyncracy. This is because the elements of perception involved are generalizable to other aspects of human experience, especially extreme states of consciousness.

One point of commonality is that persons tend to describe the wilderness experience in terms of enhanced states of perception or awareness. Another element is the tendency to describe such experiences in mystical, spiritual, or religious terms. Persons who have studied these experiences find that the subjective feelings described are very similar to those found in studies of the religious experience in general.

It is helpful to think of wilderness as serving as a catalyst for persons seeking a state of altered consciousness. In this sense, the wilderness does not "give" the person the wilderness experience, so much as it serves as a vehicle for such perceptions. This is a function of setting conditions in which such perceptual focusing is possible, a set of beliefs within the person that such states are desirable (people generally do not have either wilderness experiences or religious experiences if they do not consider them desirable, although people may attain such states without consciously aspiring to them), and a belief that such settings are likely to produce such experiences. In the same sense, a church does not give a person a religious experience; rather, it is seen as a place in which such an experience appropriately occurs. Also, as in a church, social reinforcement may help a person attain such experiences.

It is important to emphasize that such experiences are tangible and perceived as real. Further, the outcomes of such experiences in wilderness are essentially the same as those of a religious experience: a sense of meaning, order, transcendence, and communion.

What makes a person satisfied with what is encountered in the wilderness setting? This is a complex topic, as satisfaction is a multidimensional concept. Many elements go into a determination of satisfaction. However, research has consistently shown that the two most commonly cited sources of dissatisfaction are the presence of others and evidence of human impacts, especially litter. The evaluation of the presence of others is variable across settings and persons. The presence of litter, however, is among those most consistently recognized negative impacts across the range of research examined.

Many factors affect people's perceptions of wilderness and their behavior while in the environment. Some of these are amount and type of previous experience, infor-

mation previously exposed to, background characteristics, social group forces, one's emotional state, and the environment itself. People are not static entities, and their behavior patterns can change over time. Such changes can be a function of evolution in technology or in the conditions in the environment, through changes in the person's life cycle, and changes in the types of experiences sought, such as the growing desire to experience challenge and risk.

There is an increasing tendency to study what influences visitor behavior, with the intent to affect behavior for management considerations. For instance, social group forces have been shown to be very important in influencing norms of appropriate behavior. If such forces could be tapped, they would be very powerful vehicles for behavioral compliance.

The area of behavioral influence that has been most studied is the use of information. Attempts have been made to use information to encourage visitors to stay away from more heavily used areas and to adopt appropriate behaviors, such as minimum-impact practices or taking precautions against natural hazards. The results of such studies have been mixed, suggesting there might be more to influencing human behavior than just giving people information. These considerations should form the basis for future research efforts. Indirect means of managing people in wilderness are of growing importance.

Questions of appropriate behaviors and administrative response to calls for different types of opportunities suggest that the notion of wilderness management is challenging. One of the other papers in this collection deals specifically with the notion of wilderness management (Brown and others this proceedings). We recognize that an important input into decisions about what management strategies to use is the attitudes of visitors toward those management strategies and it is to this topic we next turn.

ATTITUDES TOWARD WILDERNESS MANAGEMENT

Many studies have been conducted on the attitudes of wilderness visitors toward various management actions. In some situations these actions have been planned; in others they have already been implemented and visitors are responding to their presence. The studies cover a period of over two decades, and there have been some major shifts in opinion about management as there have been in attitudes toward wilderness in this country.

One of the most important sets of attitudes visitors possess deals with the management of wilderness.

Managers seek information on visitor attitudes toward management actions for a variety of reasons. Will visitors support a change in management or do they support the current program? How strongly do they feel about some proposed action? Which segments of the public are supportive of some action and which are opposed? All of these are legitimate issues that managers might seek input on from attitude studies. Data on visitor attitudes, however, need to be put in the context of the other factors that influence decisions.

We need to stress that attitudes are not a prescription for management. Laws and policies might often dictate certain actions that are not popular. In these cases, managers can use attitude information to help reveal potential dissatisfaction, thereby alerting them to the need for programs that explain the rationale for such actions. Such efforts might not change the opinions people have concerning the action but could increase their knowledge and lessen the chance of conflict.

In other cases, people's attitudes are based on poor or incomplete information about the management action and fail to account for consequences that might be detrimental to wilderness values. To follow such attitudes irrespective of these outcomes would be irresponsible. At the same time, a knowledge of these attitudes would be helpful in designing programs that upgrade visitor understanding.

Because attitudes predict behavior only partially, managers need to be careful about placing excessive reliance on attitudes as a guide for management. Even where strong opinion about some matter is registered, it is still possible that visitor behavior might not reflect the expressed attitude. This is particularly the case in situations where the attitudes are expressed in general terms; most research literature points to the typically low predictability of such attitudes for estimating behavior (Wicker 1969). Heberlein and Black (1976) demonstrated that as the specificity of attitude scales increased from general environmentalism to measures of personal norms of nonpolluting behavior, so did the correlations between the scales and behavior. However, the authors also noted that general attitudes remain important foci for study; they influence a wide range of specific beliefs and, indirectly, a number of behaviors.

While there are limitations to the use of attitudes by wilderness managers, we want to emphasize strongly that the systematic review of visitor attitudes is essential for effective management. Numerous studies point to the differences that exist between managers and visitors about a whole range of concerns (Hendee and Harris 1970; Peterson 1974a). Often the views of visitors differ significantly from those held by area managers, and it is important that these differences be clearly understood. In some cases the views of visitors will offer viable alternatives to managers. In those cases where manager perspectives prevail, it is important that effective programs identifying the rationale and basis for decisions be formulated.

Systematic attitude surveys also provide a means of balancing the selective perception that affects us all. Wilderness visitor surveys reveal a diverse body of opinion; not all visitors want facilities or oppose restrictions. The experiences that managers have in dealing with visitors can sometimes contribute to generalized conceptions about what visitors want or oppose that are simply inaccurate (Hendee and Pyle 1971). Systematic feedback on attitudes helps counter these misconceptions, thereby avoiding actions based on imagined concerns.

In the following review, we will examine the attitudes of visitors toward four broad areas of concern: management of environmental conditions, management of trails and access, management of campsites and facilities, and management of visitor use.

Management of Environmental Conditions

Today, we largely take for granted the general condition of wilderness and appropriate uses and activities, in part because of the definition embodied in the Wilderness Act. But it is important to remember just how recent this codified definition is and how differing conceptions characterized the situation only a few years ago. The question of the appropriateness of resource exploitation activities, the control of fire or insects and diseases, or the role of active intervention in ecological processes was, less than three decades ago, something about which there was a great deal of diversity.

A brief review of some of the findings of Outdoor Recreation Resources Review Commission (ORRRC) Study Report 3 (1962) reminds us of this diversity of opinion as well as the crystallization of the wilderness concept as we know it today. The survey included visitors to the Mount Marcy area in the New York Adirondack Forest Preserve, the Boundary Waters Canoe Area in Minnesota, and a portion of California's High Sierra, including parts of Yosemite and Sequoia-Kings Canyon National Parks and the High Sierra Primitive Area.

The study provided clear evidence that most users considered wilderness as a place where exploitative activities should be limited. Between two-thirds and 85 percent felt wilderness should be left untouched and that resources, such as timber and minerals, in wilderness should not be utilized. Yet, from 16 to 34 percent were undecided or felt such resources should be utilized.

Respondents were also queried as to whether humans should try to control and manage wildlife and vegetation in wilderness or whether natural forces should be allowed to proceed with minimum interference. Again, the predominant response was in favor of the minimal interference approach; between 60 and 80 percent of the respondents preferred to let nature run its course. Nevertheless, between 20 and 35 percent indicated that control and management should be exercised.

These data indicate that scarcely two decades ago there was a significant minority view among wilderness visitors that such areas should be open to traditional resource development activities and that active environmental management was appropriate. As we continue this review, the dramatic shifts in opinion on these issues will become apparent. Yet they remind us of the constantly evolving nature of our conception of wilderness and the likelihood such conceptions will continue to change.

Even after passage of the Wilderness Act, ambivalence about management of the environment persisted. Hendee and others (1968) asked visitors to three wildernesses in the Pacific Northwest a series of questions about the appropriateness of selected resource management activities in such areas. Virtually all felt that human-caused fires and outbreaks of nonnative insects or diseases should be controlled as quickly as possible; nine out of 10 disagreed with the idea of allowing natural events, such as lightning-caused fires and infestations of native insects or diseases, to run their course; and a similar proportion supported the idea of artificial restoration of areas denuded by fire, insects, or disease.

These early data suggest that the conception of wilderness held by many visitors consisted of two parts. At one level, there was a general consensus that wilderness was a place of natural conditions where normal management activities were inappropriate. However, at a second level, there was a tendency to support intervention to control the outbreak of natural forces such as fire—a position that contradicted the more general level of support for minimum interference, but that was consistent with a conception of wilderness as a place of recreation and scenic beauty. This contrast between the general and the specific attitudes held by wilderness visitors is characteristic of attitudes in other domains. It is also reflective of a particular time in history; the concept of wilderness in the late 1950's and early 1960's was evolving and consolidating. The exact nature of those areas that were to be wilderness was not agreed upon, and the diversity of opinion, particularly at the specific level, reflects the different, often conflicting, views that existed at that time.

In the ensuing years, the conception of wilderness, especially within agencies, has taken on more specific form. Much of this specificity was shaped by the Wilderness Act itself; timber harvesting, for example, is simply not permitted. Moreover, the idea of wilderness as a place where natural forces predominate, where human intervention is the exception rather than the rule, has come to have greater acceptance. Consequently, our review of the literature did not reveal any recent studies that examined attitudes toward such issues of environmental management as insects or diseases. However, a major public policy issue concerns the role of fire in wilderness. A review of the shifting pattern of attitudes toward fire will help illustrate how rapidly such dispositions can shift, as well as indicate their relationship to the decision process.

Fire.—Although the Wilderness Act contains authority for the control of fire, it was recognized early that fire was perhaps the dominant force shaping the vegetative mosaic in many areas. Years of successful suppression had altered the natural successional process greatly, and it was clear that if such areas were to be areas where historical ecological processes operated substantially beyond human control, our attitudes toward fire and the expression of the attitudes in terms of organizational policy needed to change. Since passage of the Wilderness Act, we have seen an evolution from complete fire suppression to planned fires in some areas to help restore earlier disturbances.

Few other forces have played such a major role in giving form to wilderness. Moreover, few other environmental forces produce such deep emotional responses among the public. The fear of fire and its impacts, both environmental and economic, helped generate development of fire control policies and technologies that have brought fire under substantial control over the past 60 years.

Increasingly, however, there has been recognition that the control of fire in wilderness is contrary to the objectives of protecting natural ecological processes. Consequently, there has been a progressive switch from fire control to fire management. With this policy move, increased attention has been devoted to public attitudes. This is a relatively recent phenomenon; early studies of wilderness

visitors provided little coverage regarding attitudes about fire. For example, the ORRRC (1962) provided no direct data regarding attitudes about fire suppression policy, but did note that between 70 and 93 percent of persons sampled in seven areas felt trees should be replanted in burned areas within wilderness. Hendee and others (1968) investigated three wilderness fire-related items in their work on three Pacific Northwest wildernesses. Ninety-eight percent of respondents felt human-caused fires in wildernesslike areas should be put out immediately, 95 percent felt lightning fires should not be allowed to run their course, and 90 percent felt wildernesslike areas denuded by fire should be restored as soon as possible.

As interest in allowing fire a more natural role in wilderness ecosystems grew, more research attention on public attitudes toward fire occurred. Lucas (1980), reporting on his 1972 surveys of visitors to nine wildernesses and other roadless areas, found between 15 and 30 percent favored a natural fire policy, about one-third were neutral, and between 40 and 60 percent thought such a policy undesirable. In a 1982 followup in three of the previously studied areas, he found that support had reached nearly 50 percent, with less than one-third opposed (Lucas 1985). Visitor attitudes toward fire had clearly become more favorable.

Stankey (1976) studied the relationship between the attitudes that Selway-Bitterroot Wilderness users held about fire management and a number of other variables, including age, education, wilderness experience, and the respondent's score on a test of fire knowledge. He found that a policy of no suppression was rejected by most respondents, but 43 percent also rejected complete suppression. Overall, suppression was favored.

There was a strong relationship between the attitudes toward wilderness fire policy and knowledge of fire effects. As test scores rose, so did the likelihood the respondents would favor a modified suppression policy. A gamma of 0.57 was found between the test score and the number of times that policy was selected as "most acceptable." The more people knew about fire, the more they favored a policy of restoring a more natural role to fire.

The data from the Stankey study were collected in 1971, at a time when modified wilderness fire suppression was just becoming a major public concern. Later, McCool and Stankey (1986) repeated the study, using the same methodology, with visitors to the Selway-Bitterroot Wilderness. The average score on the fire knowledge test rose 11 percentage points, from 53 percent to 64 percent in the period. Moreover, there was a nearly 50 percent decline in 1982 in the percentage of individuals scoring in the very lowest category and a major increase in the percentage scoring in the highest two categories.

There was also a corresponding shift in attitudes toward appropriate fire suppression policies. In 1971, 56 percent of the users questioned favored a fire suppression approach. The 1984 study indicated that only about 17 percent favored these policies and only 5 percent supported complete suppression. Interestingly, only a very small percentage in either year supported a policy of completely letting all fires burn, suggesting that visitors remain unwilling to support extreme positions. Over 70 percent of the 1984 sample supported a policy of allowing some fires to burn in wilderness.

McCool and Stankey (1986) also report on visitor attitudes toward the use of scheduled prescribed fire or fire ignited by managers in wilderness according to an approved fire prescription. Nearly 50 percent felt that such scheduled prescribed fire would be beneficial while slightly more than one-third indicated they were "unsure." Only 16 percent felt that such fires would be detrimental. Of those aware of the practice of prescribed fire outside wilderness, 27 percent were unsure of the effects of scheduled prescribed fire in wilderness. This is in contrast to those who were unaware of prescribed burning; 51 percent were unsure of the effects of scheduled prescribed fire in wilderness.

Management of Trails and Access

Trail systems are a primary influence on the movement of recreationists in a wilderness. They also have the potential to affect a visitor's experience in either positive or negative ways. Thus, trail management is an important component of wilderness management.

Trails are, by definition, impacts on the environment. In some areas, the lack of trails would make travel difficult if not impossible. Elsewhere, cross-country travel can be undertaken with little trail development. Trails are especially important for certain types of use, such as horseback travel.

But while trails are impacts that are generally acceptable and expected, it is clear there are limits to the nature and extensiveness of their development, the standards to which they are built, and the locations in which they are placed. Many trails that cross wilderness areas are a product of the period of major fire control and were intended to move people and equipment from one point to another quickly and efficiently; they were not designed to move people through a wilderness with minimum impact, or improve the quality of their experience.

A number of studies report visitor attitudes toward trails. Hendee and others (1968) summarized these attitudes, noting "Trails should be developed and maintained appropriate for the use received—of varied quality and not of uniformly high standard throughout wilderness-type areas." However, they also found little support for very low-standard trails (blazed routes) and even less support for trails surfaced with sawdust or woodchips to control dust.

Stankey (1973) found mixed opinion about appropriate trail standards. The response to providing more high-quality trails (no further definition was given) was evenly mixed among those favoring, those rejecting, and those neutral to such an action. Like Hendee and others (1968), he found that those users classified as being more purist in their wilderness orientation tended to be less supportive of high-standard trails. Among visitors to Idaho's Salmon River, Tarbet and others (1977) reported strong support for low-standard trails and leaving fallen trees across trails. This support appears particularly linked to the role of such practices in controlling access. Visitors appear to recognize that the quality of access can have an effect on the amount of use an area receives; the question as to what is an appropriate level of development for trails becomes enmeshed in the question of how access will affect the use of an area.

This concern with the effects of access on the use of an area surfaced in a study by Stankey (1980) comparing use in a lightly used wilderness in the Northern Rockies with use in a heavily used wilderness in California. In both areas, about half the respondents favored reducing the number of trails and the blocking of access roads back from the wilderness boundary as a way of controlling use. Again, it is possible to interpret these results as reflecting a particular disposition toward access into the area or as a way of controlling use other than direct regulation. The data do suggest that visitors recognize the important role access plays both in the amount of use an area receives and the distribution of that use. Lucas (1964b) found little support for the idea of straightening or blacktopping roads leading to the Boundary Waters Canoe Area—further evidence of the recognition by visitors that such developments can alter greatly the nature of use in an area.

Murray (1974) queried Appalachian Trail users as to their attitudes toward two possible trail management practices, including side trails to bypass rough or steep sections and marking trail sections as to their difficulty. In both cases, approximately three out of four respondents said they favored these steps or that it didn't matter. Those hikers with the most experience tended to differ slightly from others, being less favorable to both actions.

Echelberger and Moeller (1977) found that visitors to the Cranberry Backcountry in West Virginia were predominantly in favor of what they had; about four out of 10 said "don't change" when asked about adding more foot trails and providing areas with no trails. One-third did support more foot trails, but fewer than 20 percent favored the addition of areas with no trails. This status quo position is not unlike the response of many people about proposed changes in familiar settings. Womble and others (1978), in a study of hikers on Alaska's Chilkoot Trail, found many specific comments about the trail and its condition, but the predominant message was "keep the Trail as is."

A knowledge of trends in attitudes toward trail conditions is generally lacking. One important exception is found in data reported by Lucas (1985). His analysis revealed that between 1970 and 1982 in the Bob Marshall Wilderness complex in western Montana, support for high-standard trails, defined as wide, with steady grades and fairly straight, grew significantly (table 1). Complaints about trail conditions grew sharply in the 12-year period, becoming one of the major responses given by visitors to a question regarding perceived changes in the area. The support for high-standard trails is in contrast to the general support expressed by visitors for a more primitive, undeveloped approach to management. This is likely due to the severe deterioration in trail conditions in much of the area. Visitors traveling on horseback were more in favor of high-standard trails than were backpackers; the reverse was true for low-standard trails, defined as being somewhat like a game trail—narrow, grade varies, winding, not the shortest route. Over the study period, however, support for low-standard trails appears to have diminished slightly.

Trailless areas were strongly supported by respondents in the Lucas study and there was little change over the study period; 70 percent in 1970 and 73 percent in 1982 supported such areas and there was little difference between horseback and foot travelers.

The construction of bridges is another access-related issue. Different arguments are raised regarding such structures, but typically matters such as public safety and effects on use distribution are cited. In those studies where questions about bridges have been raised, the pattern appears to be one of public support. Stankey (1973) found that nearly two out of three persons favored the construction of wood bridges across wide rivers; safety is likely a factor in this response. Those visitors classified as more purist tended to be less supportive. Echelberger and Moeller (1977) found that Cranberry Backcountry users were split on the issue of bridges, with nearly half content with the current situation, but another third wanting more.

Again, Lucas (1985) noted a shift in attitude toward bridges over the period 1970-82, with the general trend toward increasing support. In response to an item "bridges over rivers that are dangerous for hikers to wade or for horses to ford," support rose from a four to one margin in 1970 to over seven to one in 1982. Support also grew for bridges over small creeks where one could get wet feet.

Signs represent an important component of the wilderness access system. Hendee and others (1968) examined a number of questions about signs. The overall conclusion was that people preferred wood signs, showing directions only (as opposed to interpretive messages), located at trail junctions rather than concentrated at trailheads. Those users classified as more purist showed a slight tendency to support the preferences expressed by the largest percentage of other users. The authors also noted that most ques-

Table 1.—Visitor opinions of high and low standard trails, 1970 and 1982 (source: Lucas 1985, p. 29)

Year	High standard				Low standard			
	Desirable		Neutral	Undesirable	Desirable		Neutral	Undesirable
	Percentage of total visits							
1970	45		23	33	63		22	15
1982	A[1]	B			A	B		
	32 ± 3	40 ± 4	12 ± 3	16 ± 2	52 ± 4	7 ± 2	23 ± 4	18 ± 3

[1]In 1982, there were two possible desirable responses—A, "desirable," and B, "desirable in more heavily used parts of wilderness, but not in more lightly used parts."

tions produced a fairly large neutral response, ranging from 30 to 40 percent, suggesting a lack of clearcut opinions or simply that signs were of little importance.

Tarbet and others (1977) also found a lack of clear opinion with regard to signs among users on the Salmon River. The mean scores on four items related to signing all clustered on the neutral rating (an overall mean of 2.1 on a 3-point scale). The authors observed that experience likely plays a major role here; they note "infrequent users are likely to approve of these management techniques while frequent users might be opposed."

Lucas (1985) found that opinion about interpretive signs onsite shifted sharply over the period 1970 to 1982. While such signs were opposed by a two to one margin in 1970, they were favored by a small margin in 1982. Support was inversely related to experience; novices were supportive of such signs while experienced users were opposed.

The lack of signs marking trails was a major concern of visitors to the Linville Gorge and Joyce Kilmer/Slickrock Wildernesses (Roggenbuck and others 1982). Although problems with signing ranked among the top 10 as perceived by users, only about a fourth of the visitors, in fact, described it as a problem.

In summarizing attitudes toward trails and access, several points can be made. First, visitors want adequate access that accommodates their style of travel; muddy bogs are not adequate transportation networks for hikers or horseback travelers. Second, a diversity of trails is needed to accommodate different styles of travel as well as different experiences. For example, there is support for trailless portions in most areas but there is also support for areas of trail development. Third, much of the concern with trail systems does not focus on the extent of the system (indeed, there is support for maintaining what there is in most studies), but with the maintenance of that system. Finally, trails are perceived by virtually all visitors as an appropriate and necessary feature of the wilderness setting; bridges are also considered in keeping with the area's designation.

Adequate signing, including basic directional information, appears to be considered appropriate to most visitors. Moreover, the Lucas data (1985) suggest that even limited interpretive signing is not unacceptable to many. Under current Forest Service policy, these latter types of signs are prohibited; only signs providing routing information are permitted. Consequently, other types of information need to be provided by other means, such as maps or brochures. We will look at attitudes toward these techniques subsequently.

Management of Campsites and Facilities

Campsites are a particularly important aspect of visitors' images of wilderness settings. For overnight visitors they represent locations where many of the wilderness values that prompted the visit are enjoyed. Because they are the foci of use, they receive a great deal of management attention; thus, important questions of appropriate development arise. In this section we review the findings of a number of studies that examined visitor attitudes toward campsite development and associated facilities such as toilets, corrals, and firerings.

Stankey (1973) asked visitors to three western wildernesses and the Boundary Waters Canoe Area (BWCA) if they favored more campsites. Only about 20 percent of those in the western areas favored this action. In the BWCA, nearly half of the respondents were in favor of such a step. The difference appeared related to the generally wide availability of sites in the West as opposed to the more constrained situation in the BWCA.

Echelberger and Moeller (1977) found opinion evenly split on the provision of walk-in primitive campgrounds in the Cranberry Backcountry, with about a third in favor of adding more, another third saying "don't change," and the final third with no opinion.

In a study of backcountry users in Michigan's Sylvania Recreation Area, West (1981) found that among those visitors reporting they felt crowded, about 70 percent favored keeping the number of campsites at current levels and another 20 percent favored a decrease in the number. Among those who did not feel crowded, 81 percent felt the current number of campsites was satisfactory and only 3 percent favored a decrease.

Merriam and Ammons (1967) reported little support for simple campgrounds (defined as including tables, stoves, hitching racks, and outhouses) in either the Mission Mountains Primitive Area or the Bob Marshall Wilderness, but slightly over half the visitors to the wilderness backcountry of Glacier National Park supported such developments.

Among river runners in Dinosaur National Monument, Roggenbuck and Schreyer (1977) found that more users opposed than favored campsite development suggestions. Users were even more opposed to returning campsites to a more primitive or natural condition than to the proposed development, suggesting that existing sites and their condition are generally found satisfactory by users.

These limited data provide reasonably clear evidence that any appreciable effort to expand the number of wilderness campsites has little visitor support. From a management perspective, conducting inventories of potential sites could be useful as a means of reducing impact and crowding at existing sites; visitors might feel such efforts simply lead to more use. Also, the idea of providing more campsites in wilderness might conjure up images of car access style campgrounds that visitors see as inappropriate.

Toilets.—Toilet facilities are a concern in many areas. Problems of threats to human health and objectionable esthetics have led many to consider whether some type of installed toilet facility is desirable. ORRRC Study Report 3 (1962) initially pursued this matter, discovering wide-ranging opinion in their three study areas; 70 percent of visitors supported toilet facilities in Mount Marcy, 50 percent in the BWCA, but only 36 percent in the High Sierra. Shortly after the ORRRC study in the BWCA, Bultena and Taves (1961) reported that nearly 80 percent of the canoeists they interviewed there rated toilets as important.

Hendee and others (1968) found that about half of the respondents in their study supported toilet facilities in wilderness, but those rated more purist in attitude tended to strongly oppose such facilities.

Stankey (1973) found a variable pattern of support for toilets across the four study areas he investigated. Consistent with earlier findings, visitors to the BWCA were

most supportive—nearly two-thirds favored placement of toilets. In the West, only about one-fourth of the visitors to the Bridger Wilderness and High Uinta Primitive Area favored toilets, but 43 percent of visitors to the Bob Marshall did. Two likely possibilities explain these results. First, the support for toilets is based on their perceived need. In the BWCA, for instance, the extensive water area and limited soil cover help contribute to concerns about pollution, particularly because most campsites are on lakeshores. Thus, toilets are seen as a way of controlling a potentially serious problem. Second, the presence of toilets (or other facility) likely contributes to acceptance; at the time the study was conducted, toilets were still commonly found in the Bob Marshall.

Lucas' trend study (1985) reported that while toilets were equally supported and opposed in 1970, opposition to them grew to a two to one margin by 1982. Womble and others (1978), however, reported that 80 percent of the hikers on the Chilkoot Trail felt toilets were an appropriate facility along the trail; it is likely hikers perceive the Chilkoot to be more of a "historic" trail than one traveled for its wilderness appeal. Schreyer and others (1976) also found that whitewater travelers saw toilets as appropriate, but preferred pit toilets to more developed restrooms. Again, visitor attitudes appear linked to site-specific characteristics and these make simple generalizations regarding support or opposition difficult.

Firerings and Fireplaces.—Other facilities that have attracted management concern are firerings and fireplaces. There are concerns that permanent firerings attract use; in many areas it is common practice for wilderness rangers to dismantle them with the idea that users will not always camp at the same location, thereby reducing site impact. On the other hand, there is concern that fires can lead to site impacts, such as soil sterilization (Cole and Dalle-Molle 1982) and that dispersing firerings will simply increase the aggregate area so affected.

A variety of studies have probed visitor attitudes toward firerings and fireplaces. Early studies (for example, Bultena and Taves 1961) suggested in general that such facilities were acceptable in wilderness. Lucas (1964b) found that canoeists in the BWCA favored movable firerings to iron and cement fireplaces. Hendee and others (1968) reported substantial opposition to permanent fireplaces in wilderness, particularly by purists; about 50 percent endorsed movable rock fireplaces, with the purists slightly more inclined to agree. Schreyer and others (1976) found that among river runners in Dinosaur National Monument, most were strongly opposed to a ban on open fires and strongly in favor of retaining fire grates; however, nearly one-half were opposed to requiring fire pans.

Lucas (1985) reported a fairly major shift in visitor attitude toward firerings and fireplaces. Whereas cemented rock fireplaces were opposed by a three to one margin in 1970, this had grown to four to one by 1982. Moreover, while loose rock firerings had been only narrowly favored in 1970, in 1982 they were favored by a 47 to 29 percent margin.

Results from research suggest that visitors find limited facilities for fire use appropriate and acceptable, with temporary firerings more acceptable than fireplaces. The practice of removing and scattering rocks from firerings probably does little to eliminate an unwanted impact from the visitor's perspective and might produce undesired environmental impacts.

Shelters.—Although typically prohibited in classified wilderness, permanent shelters do exist in many primitive, undeveloped areas; Washburne and Cole (1983) reported that 12 percent of the units in the National Wilderness Preservation System contain such developments. Some shelters have historical significance, but most are valued for their protection from the weather and, in some cases, wildlife. Hendee and others (1968) found that nearly 60 percent of visitors agreed that three-sided shelters for hikers were consistent with an area being wilderness, but purists showed a moderate tendency to oppose them. In Glacier National Park, nearly 80 percent of the respondents favored trail shelters, but in adjacent National Forest wildernesses, they were opposed by a majority (Merriam and Ammons 1967). On the Chilkoot Trail, nearly 85 percent of the hikers felt shelters were appropriate (Womble and others 1978). Again, the level of support for some action appears conditioned by the context in which it exists. Where they have existed previously or where there are mitigating circumstances that support their presence, visitor attitudes typically are supportive.

Stock Facilities.—A final type of facility includes developments related to stock use in wilderness and backcountry areas, including fences, corrals, hitching racks, and the like. Hendee and others (1968) reported a general pattern of opposition to such developments, typically with 40 to 50 percent expressing opposition and only 20 to 30 percent in favor. The fairly large block of remaining opinion was neutral, suggesting many people had either not thought about the issue sufficiently to form a position or were genuinely unable to express their view.

Stankey (1973) found fairly strong opposition to the provision of hitching racks and corrals; only 20 percent favored them and half were opposed. Even in the Bob Marshall, where horse use is common, only about 25 percent were in favor; interestingly, there was little difference in support between backpackers and horseback travelers. Lucas (1985), however, found a different pattern with regard to the provision of pole corrals at campsites; in 1970 they were favored by a four to three margin, while in 1982 they maintained a very narrow margin of support. In both years, horsemen were much more favorable toward such facilities than backpackers. The reason for the difference in the two studies' results is not clear, especially given the difference in support among horse users.

In summary, the pattern regarding campsites and associated facilities seems to suggest a trend toward support for more primitive, nonconvenience-oriented approaches. The appropriateness of any given facility seems tied to a clear recognition on the part of the user as to the need and rationale for the facility, and where this can be demonstrated support likely follows. Also, where a facility has existed previously, there tends to be more support for it than where it would represent a new addition to the setting. In both cases, any effort on the part of management to change the status quo will need to be paired with a major effort to communicate the reason for such a change; otherwise, public opposition will likely occur. Facilities

geared to a particular class or type of user are typically supported by that user, but this is not always the case; in a horse use area, uniform support for a decision to allow pole corrals cannot be assumed.

The move to a more self-reliant, less convenience-oriented user probably has its roots in two areas: the growing availability of equipment that fosters independence (such as high-quality, self-contained petroleum stoves) and the many efforts by agencies and organizations to promote more independent styles of wilderness travel.

Management of Visitor Use

Much wilderness management involves the management of use. Lucas (1973) observed that the issue is not so much a matter of whether such management will occur, but rather a matter of how it will be implemented.

There are many specific approaches to managing wilderness use, but in this review we have organized the presentation along three lines: management of information; management of recreation behavior; and direct use limitations, including quotas and rationing.

Attitudes Toward Information as a Management Tool.—There is much interest among both managers and users as to the potential role of information and education as tools for management and as alternatives to regulation and control. In many areas, much of the future management task will be hinged on an improved program of information dispersal to visitors. Recently the Chief of the U.S. Forest Service defined the wilderness management challenge as being "80 to 90 percent education and information and 10 percent regulation" (Peterson 1985).

Visitors appear to agree. Most studies reveal a decided preference for those management actions involving information and education approaches. Roggenbuck and others (1982) found the most popular management strategy in three eastern wildernesses was the provision of better information on use; nine out of 10 respondents in each area favored this strategy. Stankey (1973) concluded from his study of users in four areas that actions influencing use in more subtle, discrete ways, such as through the use of maps, were rated more favorably by users than direct, heavy-handed techniques. For example, 50 to 60 percent of the users in all areas were supportive of better maps and information pamphlets, with purists slightly less so inclined, possibly because of concerns that such information might increase use in the area.

Another source of information is the wilderness ranger program. Although these people have many duties, informing visitors of rules, appropriate behavior, and low-impact camping techniques is an important responsibility. Wilderness rangers are seen in an almost uniformly positive fashion by visitors; Stankey (1973) reported that 60 to 70 percent of the respondents favored the presence of rangers, and Lucas (1985) found a five to one margin in their favor in both years of his trend study. Hendee and others (1968) found that two-thirds of their sample disagreed with the idea that it is not necessary to patrol backcountry areas regularly. In West Virginia's Cranberry Backcountry, Echelberger and Moeller (1977) found that nearly two-thirds of the visitors felt regular ranger patrols would improve the quality of the experience. Virtually nowhere is there any evidence that wilderness rangers are an unwelcome intrusion on the visitor's experience.

Wilderness managing agencies have worked hard to inform and educate visitors in minimum-impact techniques. This approach is attractive for a variety of reasons. It takes managers out of the "policeman" role they can easily evolve into under a regulatory approach. Given the generally high level of educational attainment of wilderness visitors, a management strategy focused on the provision of information, coupled with a rationale, is likely a highly effective approach.

Lucas (1985) concluded that some of these agency efforts are paying off. In 1970, most visitors said burying unburnable trash was desirable, but in 1982, over two to one said it was undesirable. Also, in 1982 over 90 percent said that packing unburnable garbage out of the wilderness was desirable.

Thus, it appears that educational messages can result in changes in attitude. Linkage to behavior is, of course, another question. It also remains a question as to whether an educational approach to wilderness management can control effectively all the various problems that arise. To the extent that it cannot, other strategies employing regulation or even limitation might have to be instituted. What visitor attitudes exist toward these approaches?

Management of Recreation Behavior.—A wide number of techniques have been and could be implemented that focus on specific aspects of recreation behavior such as where people camp, how long they stay, or how many people are in a party.

Stankey (1973) asked respondents their opinion about two measures that would affect access into, and within, the wilderness. First, visitors were asked to respond to the idea of reducing the number of signs and trails within the area (in the BWCA, the idea was to "leave portages rough so that only those persons willing to make the effort could visit the area"). Overall opinion was split, with 41 percent favoring and a similar percentage opposing it. In the West, only about a fourth of those on horseback supported it, a reflection of concern with their ability to travel through an area. Overall support in the BWCA was a bit higher, with 47 percent in favor; surprisingly, there was no difference in support between paddling canoeists and those using outboard motors. Purists generally were more inclined to favor the action than other users.

Stankey also asked visitors about the idea of blocking off the access road at some point so that the hike to the wilderness would be longer, thereby likely filtering off some use. About 40 percent of the visitors in the three western areas rejected this approach, and in the BWCA 60 percent opposed it.

Roggenbuck and others (1982) asked visitors in the East their attitudes toward building more trails and the assignment of departure points as techniques for distributing use. The assignment of departure points received little support, with less than a fourth in each area favoring it. Between a third and a half favored building more trails.

There is an ambivalence on the part of many users toward various use distribution techniques. This ambivalence likely derives, on the one hand, from the feeling that such measures could help reduce crowding and perhaps resource impact, but on the other hand, they might simply

stimulate more use or spread impacts. However, perceived trade-offs such as these are seldom controlled in research. Thus, ambivalence might also be a function of differing assessments of the benefits and costs of these strategies.

Another common management action involves limiting party size. The rationale behind such action is that large parties might have a disproportionate impact on both the experiences of other users as well as the environment. Today, party size limits, typically between 10 and 25 people, have been established for most wilderness areas (Washburne and Cole 1983).

Party size limits are well accepted by visitors. Tarbet and others (1977) found that a group limit of 12 was rated favorably by Salmon River visitors. A similar group limit was endorsed by nearly half the Chilkoot Trail hikers (Womble and others 1978). In three eastern wildernesses, between 70 and 80 percent of the visitors supported a limit on group size (Roggenbuck and others 1982). Roggenbuck and Schreyer (1977) found that 84 percent of river runners in Dinosaur National Monument favored some sort of maximum group size. Lucas (1985) found that opinion about party size limits remained stable over the 12-year period in the Bob Marshall Wilderness complex, with over half supporting a 12-person limit and only about 20 percent opposing it.

Stankey (1973) found a range of attitudes toward party size limits. In the BWCA, opinion was split, with half opposing such action and half either supportive or neutral. About two-thirds of the paddling canoeists supported limits, while two-thirds of the motor boaters opposed them. Among visitors to the Bridger Wilderness, 70 percent favored a limit on party size. In the Bob Marshall and High Uintas, 30 and 40 percent, respectively, favored restrictions on the size of horse parties. Both areas receive significant horse use. Although a party size limit of, say, 12 would affect primarily horse groups, an analysis controlling for method of travel provided only limited evidence that backpackers supported such limits as a way of controlling horse groups; 62 percent of backpackers supported a limit of 12, but so did 55 percent of the horsemen.

In a study comparing use and attitudes in a lightly used wilderness with those in a heavily used area, Stankey (1980) examined visitor views regarding party size restrictions. In the heavily used Desolation Wilderness in California, eight out of 10 agreed there should be a limit to the size of parties visiting a wilderness, while in the lightly used Spanish Peaks in Montana, only about half agreed. Among those in both areas who felt such a limit was needed, about three-fourths felt a limit of no more than 10 people was acceptable. In the Desolation, where there is little stock use, nearly 40 percent said there should be no stock allowed, while another 40 percent felt between one and four animals would be acceptable. As with many other attitudes, dispositions are shaped by local conditions and experiences. Where these are relatively stable across areas, useful generalizations can often be made, but where sharp local differences exist, it is more difficult to make such statements.

One type of direct regulation that has received much attention in the literature involves assignment of recreationists to campsites. The rationale is that such a program could help reduce crowding at sites and could also help protect certain fragile settings.

Visitor response to campsite assignment, however, is generally negative. Echelberger and Moeller (1977) found that 42 percent of the respondents in the Cranberry Backcountry said assigning campsites would reduce the quality of the experience and only one-third thought it would improve quality. On the Chilkoot Trail, 57 percent of the hikers disagreed with such an action; one-third did support it (Womble and others 1978). Stankey (1973) found very strong opposition to campsite assignments, with over 80 percent of the visitors opposed to them and only 6 percent supportive. In a 1980 investigation, Stankey found that assigning campsites was rated less favorably than charging a fee by visitors to the Spanish Peaks and the Desolation Wilderness; only 23 and 17 percent, respectively, approved of such a step. Roggenbuck and others (1982) found only about 20 percent of the visitors in three eastern wildernesses supported campsite assignment. Lucas (1985) reported a stable pattern of disapproval to campsite assignment (roughly three-fourths opposed) in his study of trends in wilderness use between 1970 and 1982.

An exception to this general trend is found among some whitewater river runners. In Dinosaur National Monument, river runners favored an assignment system four times more than they opposed it (Roggenbuck and Schreyer 1977). This appears associated with the limited availability of campsites along the river and the feeling on the part of users that such a system offers more certainty for finding a campsite at night. In terrestrial wilderness settings, it appears most visitors prefer searching for sites and expect, even in heavily used areas, that they can find one suitable to their tastes. Even being unable to locate a desirable site, however, appears preferable to being assigned where they have to camp, a step that seems to strike at the spontaneity and freedom that motivate much use.

Schreyer and Nielson (1978) found a mixed response to assigned campsites by river runners in Westwater Canyon on the Colorado River and Desolation/Gray Canyons on the Green River. Over 55 percent of the Westwater users favored such a system, with about a third opposed; however, on the Desolation, the percentages were exactly reversed.

These and many other regulations of wilderness visitor behavior have been implemented with varying success. Use conditions and associated impacts, however, can reach a point where such regulations cannot accomplish area management objectives. At this time, it might become necessary to implement controls on use numbers through some form of rationing. In the last part of this section, we examine visitor attitudes toward direct use restrictions.

Direct Use Limitations.—The idea of restricting entry to wilderness is, in many ways, an anathema. The very idea of wilderness suggests freedom and a lack of control; restricting that freedom through the imposition of limits seems to strike at the very heart of what wilderness is all about. The dilemma arises, of course, from the fact that the view of wilderness as an unrestricted commons can lead to use levels that jeopardize the important social and ecological values such areas contain.

Despite these concerns, many users express a general willingness to accept limitation. One exception was reported by Hendee and others (1968); almost five out of 10 persons did not feel that use of wilderness-type areas needed to be restricted and only 30 percent agreed it did. However, these data were obtained over 15 years ago, at a time when use in many areas had not reached the levels it since has. Lucas (1985) found that visitors in both 1970 and 1982 strongly supported the idea of "restricting the number of visitors to an area if it is being used beyond capacity" (no definition of capacity was given); over three-fourths answered that this was desirable and only 12 to 14 percent said it was undesirable. Tarbet and others (1977) found that the management option of restricting the number of users received a mean score of 2.9 on a scale of 3 (with 3 being desirable); this was the highest mean score recorded on any possible management action about which visitors to the Salmon River were asked.

Stankey (1980) asked visitors to the Spanish Peaks Primitive Area and Desolation Wilderness to respond to three statements concerning how they felt about management actions that should be taken if use were to continue to increase. First, it was suggested:

> It would be better to be able to go to the wilderness whenever you want to, even if it was being used beyond capacity, than to have any kind of regulations on use.

In response to this item, 83 percent of the Desolation visitors and 74 percent of the Spanish Peaks visitors expressed disagreement. It is clear from the response that unrestricted entry, when capacity has been exceeded, is not acceptable. Desolation visitors were more inclined to disagree with the statement than Spanish Peaks users, but this seems consistent with the much higher use there.

Users were then asked to comment on two additional items:

> There should be restrictions on how many people can be in a wilderness at any given time.
>
> and
>
> If a wilderness becomes overcrowded, restrictions on the number of people allowed to visit it should be enforced.

About half of the Spanish Peaks visitors agreed with the first statement; in the Desolation Wilderness, nearly nine out of 10 agreed. However, in the second item, which at first appears to merely restate the first, the differences in attitudes between the two were much less sharp, although still statistically significant; nine out of 10 of the Desolation visitors agreed with it, and three out of four of the Spanish Peaks visitors also agreed. The difference appears linked to the fact that the first statement proposes use restrictions without considering carrying capacity. In the Spanish Peaks, where use levels were low and most visitors felt the area's capacity had not been exceeded, only about half agreed with it, but nearly 90 percent of the Desolation Wilderness visitors agreed with the statement, an outcome that can probably be attributed to the high use levels currently found in the Desolation.

With regard to the second item, support for restricting use when the area became overcrowded grew sharply in the Spanish Peaks; by adding the crowding proviso, the item took on a condition with which most Spanish Peaks visitors could concur.

Interarea differences in use also yielded differences in attitudes toward control in three eastern wildernesses studied by Roggenbuck and others (1982). The major difference among areas was when the need to impose controls might arise. In the Shining Rock, which has one of the highest use densities in the country, nearly one-fourth thought controls were needed immediately to lower use, another 30 percent thought they were needed now to hold use at current levels, and nearly 40 percent thought they would be needed in the future. In the Joyce Kilmer/Slickrock, on the other hand, a lightly used area by eastern standards, the majority of users felt controls would be needed, but only in the future and when overuse occurred. In all areas, there was little support for the idea that controls were not needed at present or in the future.

Bultena and others (1981b) found strong opposition among Mount McKinley (Denali) National Park backpackers toward allowing uncontrolled use levels in the backcountry. Womble and others (1978) found divided opinion among Chilkoot Trail users; in response to the item "the number of hikers on the Trail at any given time should be limited," 37 percent agreed and 38 percent disagreed, while in response to "the number of hikers in camping areas at any given time should be limited," an identical 39 percent agreed and disagreed. A wide variety of reasons for these views were presented, ranging from support based on concerns for resource protection, to opposition based on concern for the protection of personal freedom, and even some based on the fact that historically there had been no limits to the Trail. Schreyer and Nielson (1978) found that only about 6 percent of whitewater river runners were in favor of removing all restrictions on the number of users on rivers; between 80 and 90 percent were opposed to such a move.

While there is generally strong support for the idea of restricting wilderness use, particularly when problems of crowding or resource impact are imminent, how should such restrictions be implemented and what public attitudes exist toward these different measures? Many specific techniques have been proposed to restrict use. Each carries a different type of cost and impacts different users. Consequently, we would expect different types of users to hold different opinions about these various alternatives, opinions shaped in part by how they see the action affecting them (Stankey and Baden 1977). Five broad strategies of use restriction can be identified. These include (1) queuing (first-come, first-served), (2) reservation, (3) pricing, (4) lottery, and (5) merit.

1. Controlling use through a queuing or first-come, first-served system is a common way of regulating entry to a scarce resource. In the wilderness situation, it tends to favor the local user or the person with abundant time (Stankey and Baden 1977). Stankey (1973) found that 28 percent of respondents favored a first-come, first-served system, with another 18 percent neutral; thus, nearly half were in favor or not opposed while slightly over half were not in favor. Consistent with the resident bias noted above, he found greater support in the Bob Marshall Wilderness, where most users were locals, than in the Bridger Wilderness, where nonresidents were predominant. Later, Stankey (1980) found that Desolation Wilderness visitors favored the first-come, first-served approach substantially more than did Spanish Peaks visitors

(57 to 41 percent). Both areas draw their use predominantly from local areas; over 90 percent of Desolation visitors come from California and over 70 percent of those in the Spanish Peaks come from Montana (Lucas 1980). However, the Desolation Wilderness is one of the most densely used areas in the country while the Spanish Peaks is one of the lightest (Stankey and others 1976). Consequently, Desolation visitors tended to be more supportive of all use control measures than did Spanish Peaks visitors. Moreover, a mandatory permit system in effect at the time of the study in all California wildernesses, distributed in part through a first-come, first-served system, likely resulted in more visitors there being familiar with it.

Roggenbuck and others (1982) also found fairly strong support for queuing. Support ranged from 41 to 52 percent. The Linville Gorge had such a program in effect at the time of the study, and 50 percent of the respondents indicated support for it.

Only slightly more than a fourth of the whitewater river runners surveyed by Schreyer and Nielson (1978) favored a first-come, first-served system. Commercial passengers in Westwater Canyon were more in favor of this system than were the private runners, but this ranking was reversed among the Desolation users.

Although a first-come, first-served system tends to favor local users, Bultena and others (1981a) found strong support for such a system among backpackers in the Mount McKinley backcountry—82 percent of the users supported this system. It should be noted that the permits for Mount McKinley backcountry use were distributed through a first-come, first-served system; thus, users were familiar with it.

2. Another common system involves reservations. A reservation system tends to favor those able and willing to plan ahead and whose time commitments are more predictable (Stankey and Baden 1977). However, when reservations can be obtained freely, there is a tendency for people to obtain them even if there is only a small chance they might eventually use them, often resulting in a large share of "no shows," resulting in a suboptimal allocation of the resource. Stankey (1973) found opinion fairly evenly split among wilderness users; overall, 43 percent supported a reservation system and 39 percent opposed it. Nearly one person in five was neutral. Among purists, the reservation system was rated as most favorable.

Stankey (1980) found a sharp split in opinion in his study of the Spanish Peaks Primitive Area and the Desolation Wilderness. Only 29 percent of the Spanish Peaks visitors favored a mail reservation system, but in the Desolation, 59 percent did so. The familiarity that Desolation visitors had with a mail reservation system then in effect in California probably accounted for much of the difference. This appears to be the case in a study reported by Roggenbuck and others (1982) where 85 percent of the Linville Gorge visitors supported an advance reservation system (and where such a program was already in place), while in the Shining Rock and Joyce Kilmer/Slickrock Wildernesses, two-thirds of respondents supported such a system. In a study of river runners on the Middle Fork of the Salmon River in Idaho, Utter and others (1981) found strong support for reservation systems, likely reflecting the fact that such users typically are more familiar with such systems than most backpackers.

Schreyer and Nielson (1978) reported strong support for a reservation program among whitewater river runners; about 80 percent of those surveyed in the Westwater and Desolation Canyons favored such a program. Commercial passengers were more strongly in favor of the advance reservation program than were private runners.

Nearly half (46 percent) of Mount McKinley backpackers opposed an advance reservation system (Bultena and others 1981a) while 37 percent supported it and 14 percent were neutral.

3. One of the most common techniques in society for the allocation of scarce resources is pricing. However, when considered as a mechanism for the allocation of recreation and amenity resources in general, or wilderness in particular, pricing is often seen as unacceptable or inappropriate.

Nevertheless, several studies have looked at the use of pricing as a way of limiting use. One study (Hendee and others 1968) asked if visitors would be willing to pay some charge to help defray the costs of backcountry administration and management. More than four out of 10 persons were willing to do so, one-third were opposed; those persons who were classed as more purist in attitude were particularly opposed to such a charge.

The notion of a fee has received some support. Even at the time of the ORRRC Study (1962), charging for wilderness entry received support. That study asked, "If it were necessary to charge a yearly license fee in order to preserve wilderness, what would be the maximum price you would be willing to pay?" Slightly over a fourth replied "nothing" but another fourth replied between $3 and $5.

Stankey (1973) also found about a fourth of respondents favored a fee while 20 percent were neutral. Among purists, there was mixed opinion; overall, about 45 percent opposed a fee, but the percentage favoring one ranged from 23 to 53 percent among the different areas. This pattern persisted in Stankey's 1980 report on the Spanish Peaks Primitive Area and Desolation Wilderness. About one-fourth of Spanish Peaks visitors and one-third of Desolation visitors supported a fee. It also prevailed in a study of users in three eastern wildernesses (Roggenbuck and others 1982) where about one user in five supported it. Two-thirds of the respondents in the Mount McKinley backcountry opposed a fee and only one in 10 supported it (Bultena and others 1981a). Still, nearly 20 percent were neutral to the idea of charging.

4. The concept of a lottery as a means of allocating wilderness use opportunities has been proposed as a system that would eliminate many of the advantages and disadvantages of other distributive systems (Hardin 1969). In this system, much as in the programs that many States have implemented to allocate certain hunting permits, one's chance to visit an area would ride on the "luck of the draw."

It appears that many people are not willing to leave their wilderness visits to chance. In the four studies reviewed where attitudes toward a lottery were examined (Stankey 1973, 1980; Bultena and others 1981a; Roggenbuck and others 1982), it was the least favored of all rationing programs, ranking even below the imposition of a fee. Overall, support ranged from a low of about 6 percent to a high of around 18 percent. These results persist over a wide geographic area and over a period of 10 years, altogether a remarkable measure of stability.

A lottery also rated poorly among whitewater river runners. Overall, only about 20 percent of those surveyed by Schreyer and Nielson (1978) favored a lottery, and although private river runners were more supportive than the commercial passengers, a majority of both groups opposed a lottery. One exception to this general pattern is in Utter and others' (1981) study of river runners where they found support for the use of lotteries.

5. Rationing by merit received much attention in an article by Hardin (1969) and, even today, has many advocates. Many of the ideas underlying the concept of minimum-impact camping originate from the merit idea. The basic concept is that by requiring individuals to have some minimum level of skill and knowledge about use of the backcountry, many undesirable impacts can be eliminated, thereby reducing the need for restrictions.

Only limited data exist regarding visitor attitudes toward such an approach. Stankey (1980) asked visitors to the Desolation Wilderness the degree to which they favored or opposed being required to take a test of their wilderness skills and knowledge. Nearly six out of 10 supported such a policy. Utter and others (1981) found that a majority of users on the Middle Fork of the Salmon River supported a merit option, although the item as presented in the questionnaire might have led people to believe that it referred to their guide's experience and not their own. Bultena and others (1981a) reported substantial opposition to such an approach, with half of the Mount McKinley backpackers surveyed opposed and only about a fourth in favor.

Shelby and others (1982) examined the attitudes of river runners and backpackers toward the five general use rationing programs we have reviewed in terms of four criteria: their effect on the chance of obtaining a permit, their fairness, their acceptability to users, and the willingness of users to try them. The results (table 2) indicate that pricing and reservation systems rank highest with regard to all the criteria for both river runners and backpackers, with one exception: a merit system is seen by backpackers as having less effect on them than a reservation system.

Most studies reviewed here have tapped the attitudes of visitors toward the various rationing schemes in a hypothetical or abstract sense. However, two studies have reported attitudes toward a specific program. Fazio and Gilbert (1974) surveyed backcountry users in Rocky Mountain National Park to determine their reaction to a program instituted to control overnight use. People were surveyed both before and after they visited the area. Although people were required to wait for up to 1½ hours to obtain a permit, 69 percent of those queried in the pretest and 86 percent of those in the followup survey viewed the system as necessary. Even among those unable to obtain a permit, 80 percent still saw the permit system as necessary.

Table 2.—Percentages of users agreeing with four assessments of allocation alternatives (source: Shelby and others 1982, p. 418)

Allocation alternative	River runners Hells Canyon (N = 295)	Backpackers Eagle Cap (N = 118)	Backpackers Mt. Jefferson (N = 261)	Chi square[1] (d.f. = 2)
	Percent			
Little or No Effect on Chances of Obtaining Permits				
Pricing	48	70	54	[2]13.12
Reservation	64	56	45	[2]35.07
Lottery	31	20	19	[2]11.41
Queuing	14	41	38	[2]47.27
Merit	37	66	66	[2]46.69
System Is Fair				
Pricing	45	49	43	1.51
Reservation	78	50	48	[2]53.14
Lottery	39	19	21	[2]26.16
Queuing	12	34	29	[2]36.08
Merit	23	24	34	7.45
System Is Acceptable				
Pricing	66	66	55	5.85
Reservation	95	73	74	[2]46.19
Lottery	50	28	30	[2]23.97
Queuing	25	50	51	[2]40.40
Merit	37	42	49	5.91
Willing to Try System				
Pricing	62	68	64	1.16
Reservation	84	71	64	[2]32.32
Lottery	51	35	37	[2]11.88
Queuing	16	53	55	[2]96.35
Merit	36	56	60	[2]32.97

[1]Chi squares are based on 3 x 2 tables comparing responses across the three user groups.
[2]p<0.005.

Similar results were obtained by Stankey (1979b) in a study of use rationing in two southern California wildernesses. He found that among successful applicants, 82 percent supported implementation of the rationing system and only 5 percent opposed it. And as Fazio and Gilbert had reported, even unsuccessful applicants supported the system; 81 percent were in favor of it and only 5 percent were opposed.

The conclusions of Shelby and others (1982) mirror those that we derive from this review of visitor attitudes toward the various rationing schemes. Users generally support the idea that management policies need to be implemented to protect the quality of wilderness and backcountry experiences. There is a recognition that unlimited use is not consistent with the kinds of conditions and experiences such areas are to provide. However, when we consider specific techniques, the characteristics of different areas, activities, and clients affect judgments of their appropriateness. Because each system imposes different impacts on users, it is necessary to consider the specific characteristics of an area and its use to determine the most appropriate approach.

Bultena and others (1981a) offered important evidence as to how the orientation of visitors affects their appraisal of different management policies. Overall, their data showed that the backcountry policies at Denali National Park, although restrictive, were endorsed by most visitors. Within this broad pattern of support, however, there were sharp differences of opinion, revolving largely on the underlying orientation of the respondent toward wilderness. The investigators considered how the appraisal of different management policies varied according to the importance respondents placed on solitude and their preference for resource development (the extent to which they favored the provision of more facilities in the backcountry). As table 3 shows, those backpackers seeking solitude were also those most supportive of the need for rationing and of the existing management policies in the park. Conversely, those most development-oriented were the least supportive of rationing and the park's restrictive use control measures. However, there were generally no differences based on the alternative orientations toward specific rationing steps.

Summary of Attitudes About Management

In reviewing the results of the many studies discussed in this section, several general conclusions can be made. First, although the studies have been conducted over an extended time, over a wide geographic region, and have involved differing methods, sampling approaches, and questions, it is still possible to obtain some clear patterns regarding visitor attitudes toward management. Everyone does not have their own unique conception about how to manage wilderness. In fact, one of the major benefits of a review such as this is to help "tease out" some of these patterns and clusters of beliefs and to help managers better understand how these patterns relate to the actions they undertake and the decisions they must make. While some patterns do emerge, it is important to note that there is considerable variation in the attitudes of wilderness visitors toward management. Yet, many of these variations are related systematically to other factors, such as method of travel.

Second, although we can discern certain patterns in our review, it is difficult to ascertain trends in these patterns. With few exceptions, the body of research on visitor attitudes toward management is derived from cross-sectional studies, with limited comparability from one study to another. No longitudinal studies have been conducted; consequently it is difficult to assess what changes, if any, have occurred over time. Our review leads us to conclude that some marked changes have likely occurred and the trend study by Lucas (1985) supports this. There appears to be a move toward more appreciative, less consumptive styles of use, declining support for developmental responses to problems, increasing support for educative and information-based management responses, and a base of support for use restriction when conditions warrant it.

Table 3.—Relationships of hikers' solitude and development orientations to their attitudes toward rationing and existing management policies (source: Bultena and others 1981a, p. 307)

Policy domain	Orientation: Solitude	Gamma[1]	Orientation: Development
Desirability of rationing	+0.30		−0.38
Alternative rationing systems			
First-come, first-served	+.19		−.19
Lottery	0		+.04
Registration	−.10		+.12
Merit	+.03		+.02
Entrance or use fee	−.10		+.06
Existing management policies (management policy score)	+.17		−.29

[1]The contingency tables from which the gammas were obtained had five response categories for the "desirability of rationing" and each of the five "alternative rationing systems." The management policy score, solitude orientation, and resource development orientation were each broken into three categories. Tests were not made of the statistical significance of relationships because the full universe, rather than a sample, was surveyed.

Such conclusions rest on a limited data base. The extent to which the findings reviewed here or reported by Lucas can be generalized is not clear; it is our assessment that today's wilderness user supports a more purist perspective about wilderness management than his or her counterpart a decade ago.

A third conclusion we can make is that many studies reveal a tendency for users to support the status quo. Some of this might derive from the legitimate belief that what exists now is fine and any changes will only detract. The belief might also derive from concerns that changes will alter the character of the setting in ways that will attract more users or a different kind of user. The principal implication for managers is that cross-sectional attitude surveys provide only a measure of opinion at one time. Without a context within which to place such data, results are difficult to interpret. Being able to compare the results of one study with those obtained at a different place or time provides a basis for appraising how such results might be interpreted and used.

The expressed preference for the status quo also holds important implications for the manager contemplating change. As we stated earlier, attitudes are not a prescription for management; conditions might dictate that despite a seeming contentedness among present users, new actions must be implemented. In such cases, however, managers need to match implementation of any new action with efforts to inform users of the need and rationale for that action. Attitudes do change in response to information, and managers can play a critical role in this process.

Fourth, on virtually all issues, a diversity of opinion exists. Typically we focus on whether more people support or oppose some issue. However, we believe it is important to review the full spectrum of opinion: the level of support, the level of opposition, and the extent to which a neutral opinion exists. To be neutral is to have an opinion. It might reflect a legitimate view that it really doesn't matter, or it could reflect an equally legitimate view that people simply cannot arrive at an opinion, either because they have not had adequate time to think about it or because they lack adequate information to make a judgment. The neutral category represents an important group in situations where opinion is evenly divided between pro and con; in these situations it might represent a potential "swing vote" in public sentiment. Accurate information about the reason for some action or the implications of some step can be critical in influencing how people might move from a neutral stance.

It is also important to examine the distribution of opinion at the extremes. Strongly held views, either for or against, can be suggestive of likely behavior. When opinion is not just against, but is strongly against some issue, managers have an important indication that the issue is particularly sensitive. Proceeding with the proposed action demands care and planning lest public opposition overwhelm it.

Finally, we have seen how opinion about various management actions differs among user groups according to a variety of factors—their method of travel, relative level of wilderness experience, and intensity of attitudes toward wilderness. All these factors permit a more critical as well as useful analysis of the data. Users differ in many ways, leading them to appraise management actions in different ways. By grouping users into categories, we are able to segment the user population into subunits possessing more uniform conceptions of wilderness and its use and management. This provides a more useful method of looking at the distribution of opinion about an issue. If there is opposition to the provision of stock facilities, does it all derive from backpackers? If so, and the area provides a significant opportunity for horse use, the management response might be to separate user types. On the other hand, if there is opposition among horse users as well, then perhaps there is serious question as to the need for such facilities at all. Or, efforts to improve the stock handling capabilities of horse users need to be emphasized. In any case, a more refined analysis of the user population helps improve the ability to analyze and evaluate attitude data.

Visitor attitudes are particularly important to management in situations where there is conflict among users or feelings of dissatisfaction about existing conditions. As wilderness visitation has grown, so have perceptions of conflict and concerns for the impacts of this increased use. The following section explores these concerns and the reasons for them.

CONFLICT AND CROWDING IN WILDERNESS SETTINGS

As the last section has shown, the maintenance of wilderness requires active and diverse management. The fact that people value wilderness and desire to experience it produces a fundamental paradox: that appreciation may threaten the natural qualities that define wilderness environments. It has also raised an even deeper concern over the extent to which use should be regulated. Users are growing in numbers, coming in contact with one another, and experiencing conflict and crowding. If solitude is a fundamental aspect of the wilderness experience, the presence of others invariably impacts that experience.

The Concept of Carrying Capacity

Many have talked of the need to establish a carrying capacity in wilderness environments. The fundamental concept appears intuitively sound. It has been possible to identify carrying capacities for cattle and deer in wildland situations based on their impact on forage. Thus, it should be possible to recognize when recreational impacts are too great and use needs to be curtailed. Although such logic at first glance appears sound, the attempt to actually determine a carrying capacity is fraught with difficulty. There are many differences between complex humans moving through a wilderness and bovines browsing, though many cynics would not necessarily agree.

In this section we will discuss problems relating to visitor perceptions of conflict and crowding. Discussions of carrying capacity generally include concerns for impacts to the environment as well as the crowding dimension. The environmental impact dimension has been covered in depth in other papers in this collection. Here we focus on visitor reaction to impacts as well as to other recreationists.

There has been a substantial amount of research on the impacts of recreational use and visitor perceptions of crowding. Perhaps the most comprehensive effort to summarize this literature was undertaken by Graefe and others (1984). A related bibliography by Vaske and others (1984) is also available.

There has been much controversy over the establishment of a carrying capacity, and many have argued that the concept is not even a valid notion to apply to recreation (Schreyer 1979; Burch 1981). One of the more universally agreed on facts is that there is no such thing as *a* carrying capacity for an area. Rather, there are many possible capacities, depending on resource goals, visitor distribution and behavior, and environmental characteristics. Thus, rather than talk of *a* carrying capacity, it is more appropriate to consider the broader picture of managing for and regulating recreational use. This might require use limitation, but there can be many other ways of dealing with impacts or conflicts.

Graefe and others (1984) presented a model of the dynamics of visitor response to others in terms of two conceptual lines of inquiry. The first was expectancy theory, which assumes that people develop expectations for what they will encounter and then gauge what is actually encountered against those expectations. This is one of the fundamental underpinnings of the motive approaches to understanding visitor behavior described earlier.

Expectations can be general and diffuse, such as the expectation to experience nature. They can also be quite specific. For instance, a person might expect to camp at a specific campsite on a given lake with no other persons there. A person might desire to participate in wilderness recreation to experience solitude. The choice of a particular environment is based on the expectation that few people will be seen. If more people are seen, this can lead to dissatisfaction. Depending on the level of specificity, an expectation might be more or less strongly tied to feelings of dissatisfaction when encounters with others are greater than desired.

Their second line of inquiry was that of norms. Norms are standards for evaluation of behaviors, persons, or situations (Cancian 1975). As norms are invariably socially influenced ways of looking at the world, we view shared norms as "social norms" (Black and Heberlein 1976). People can share norms concerning what the appropriate level of use for an area should be, as well as what should be appropriate behaviors of users and levels of impact to the environment. To the extent these norms are reasonably well-defined among group members, they should be measurable and standards for levels could be established.

Crowding can occur when numbers of others exceed one's expectations. These expectations can be shared in a social context and formalized as norms. Different dynamics can be used to explain these workings. "Discrepancy" models suggest dissatisfaction is a function of the gap between what was expected and what was encountered (Peterson 1974b; Becker 1978; Schreyer and Roggenbuck 1978). "Social interference" models imply that negative outcomes arise when the presence or behavior of others interferes with the individual's attainment of desired goals (Jacob and Schreyer 1980). "Stimulus overload" models are founded on the notion that problems arise when encounters with others result in greater social interaction than desired (Baumgartner and Gundry 1978; Gramann 1982). All these models agree that it is necessary to understand the experiences and outcomes sought by recreationists to understand their reaction to encounters with others (Graefe and others 1984).

The Assessment of Crowding

There is tremendous complexity in the human response to the natural environment. Given this complexity, there is a temptation to avoid comprehensive examination of these issues by concluding "everyone is different" and managing for the mythical average visitor or the lowest common denominator of human perception. However, simplifying such complexity does not resolve problems resulting from too many visitors to the wilderness; rather, it demands a more sophisticated understanding of the forces at work in assessing perceptions of crowding.

Human response to others is affected by a variety of background and situational variables. We can easily assess the objective dimensions of human interaction. Increasing use levels in wilderness can be shown to relate to an increasing level of encounters among visitors (Shelby 1976, 1980b; Heberlein and Vaske 1977; McDonald and Hammitt 1979). Increased encounters are generally associated with increased perceptions of crowding (Schreyer and others 1976; Bultena and others 1981b; Womble and Studebaker 1981; Hammitt and others 1982; Graefe and others 1984). However, density is not equivalent to crowding. Density refers to the number of individuals in a given setting, while crowding relates to the negative evaluation of that density. That evaluation is affected by many factors (Altman 1975).

Problems from the presence of others might not result from direct encounters. People can respond more strongly to impacts perceived as being caused by others than actually seeing them (Lee 1975). In many cases, visitors are likely unaware of impacts (Cole and Benedict 1983). Even if the impact is noted, it might not have an adverse effect on the visitor's experience if judged not to be important (Lucas 1979; Graefe and others 1984). Further, visitors might be more sensitive to evidence of humans, such as litter, than to actual impacts to the environment, such as eroded trails (Frissell and Duncan 1965; Stankey 1973). Impacts cannot only result in negative reactions, but can increase perceptions of the use levels of an area (Ditton and others 1983). Vaske and others (1982) found that "environmental disturbance" was the strongest predictor of perceived crowding in a wilderness.

Crowding, Satisfaction, and the Recreation Experience

A fundamental notion involved in these concerns is the belief that the perception of crowding negatively impacts the wilderness experience. This has usually been studied through an assessment of recreationists' satisfaction with the numbers of others encountered. Because the concept of recreation resource management is founded on the notion of providing opportunities for visitors to attain

satisfaction, this appeared to be the most direct method of analyzing crowding.

Unfortunately, the situation has not been as straightforward as originally assumed. In many cases, use levels have not been related directly to satisfaction. Graefe and others (1984) summarized 36 studies measuring different dimensions of encounters and satisfaction. Of those studies measuring the correlation between actual density of an area and visitor satisfaction, only two showed a significant statistical effect, and both of those were positively correlated (Heberlein and Laybourne 1978; Heberlein and others 1982). Both involved studies of hunters in which the presence of others was seen as advantageous in driving the deer toward them.

In studies measuring the relationship between reported contacts and satisfaction, three were significant, but again two were in the positive direction (Hammitt and others 1984; Vaske and others 1983). Graefe and others (1984) did find a more consistent relationship between both actual density and reported contacts and perceptions of crowding. Further, there were consistent relationships between perceived crowding and level of satisfaction (Shelby 1976; Heberlein and Vaske 1977; Shelby and Colvin 1979; Ditton and others 1982; Vaske and others 1982, 1983).

Many of the studies reviewed by Graefe and others (1984) did not involve use in wilderness settings. Both conventional wisdom that assumes wilderness as a setting where there is little if any contact with others and research supporting visitor preference for low levels of interparty contact lead one to hypothesize that crowding in wilderness could be a problem.

Research by Stankey (1973, 1980) indicated a strong preference among wilderness visitors for low levels of interparty contact. Although responses to questions about the impact of rising use levels on satisfaction were based on hypothetical situations rather than actual use conditions encountered, the results pointed to the likelihood that visitor satisfaction declined as contact levels rose.

Lucas (1980, 1985) found evidence supporting this hypothesized relationship. The relationship between visitor satisfaction and level of use encountered, measured three different ways, was negative, although the strength of this relationship declined over the decade between the two studies.

Desired Outcomes.—The numbers of others encountered is not the sole consideration in determining satisfaction in a recreation experience. Schreyer and Roggenbuck (1978) showed that perceptions of crowding are linked to the strength of crowding-sensitive outcomes, such as stress release and solitude. However, if such outcomes are not important, the presence of others need not be disturbing (Stankey and McCool 1984). Recreational engagements are entered precisely because we want them to be satisfying. Thus, even if we would have preferred to see fewer people, we might be unwilling to let certain negative aspects such as this impact that satisfaction (Heberlein and Shelby 1977).

Schreyer (1979) suggested that people might use any number of coping mechanisms, such as emphasizing more crowding-independent outcomes and altering perceptions of the numbers of people actually present to avoid negative outcomes (Schmidt and Keating 1979; Gramann 1982). Further, people might have few strictly defined expectations about numbers of others they might encounter (Cheek and Burch 1976).

Behavior Change.—People can change their behavior patterns in response to crowding. Thus, although numbers might be high, those most sensitive to such conditions avoid situations of high density. Such behavior shifts are referred to as displacement. The extent to which displacement occurs is arguable. In a study of river floaters in the Grand Canyon, Nielsen and Endo (1977) found that, although some boaters moved to lower density rivers, others moved to higher density ones. Anderson (1980) documented displacement among visitors to the Boundary Waters Canoe Area. Although displacement was noted, she found no differences among persons based on amount of experience. Other studies have shown some displacement among visitors from more crowded to less crowded environments for a variety of water-based activities (Heberlein and Vaske 1977; Nielsen and Shelby 1977; Vaske and others 1980; Becker 1981a).

Conflict vs. Crowding.—People might respond not merely to numbers, but rather to the behavior of others (Stankey 1972). Conflict can make people more sensitive to the numbers of others, and thus make an area seem more crowded. Jacob and Schreyer (1980) define conflict as "goal interference attributed to another." They suggest that conflict occurs when others frustrate a person's desired outcomes for an experience, or when they violate norms of appropriate behavior as defined by those persons. Such norms could relate to the activity, or they could be defined as appropriate behaviors for the recreation place. Some conflicts are fueled by the perception that others possess a different lifestyle with ways of behaving and values threatening to those experiencing conflict. This is a strong force leading to conflict among different "types" of recreationists, such as hikers and horseback riders.

User Types.—Graefe and others (1984) pointed out that different types of users differ in their sensitivity to others. This again is likely due to their seeking different outcomes and having different norms about appropriate encounter levels. It is difficult to generalize perceived crowding of visitors to an area because they might differ widely in perceptions of the same encounter levels. Because different types of users perceive crowding in different ways, making decisions about crowding inherently implies a judgment favoring one type of user over another (Schreyer 1976).

Confrontation and conflict often underlie crowding perceptions. Graefe and others (1984) presented a tabular representation of a number of studies comparing crowding perceptions of different types of visitors. They dichotomized the types as "sensitive" or "tolerant" to the presence or behavior of others. Among these sensitive/tolerant types are several found in wilderness: nonmotorized/motorized water-based recreationists (Adelman and others 1982), fishermen/other water-based recreationists (Driver and Bassett 1975; Gramann and Burdge 1981; West 1982b), frequent/infrequent participants (Graefe 1981), experienced/inexperienced visitors (Nielsen and others 1977; Schreyer and Nielson 1978; Vaske and others 1980; Ditton and others 1982; Hammitt and others 1984), high status/

low status participants (West 1982a), and solitude seekers/ thrill seekers (Absher and Lee 1981).

Group Dynamics.—Many differences noted above enhance the notion that crowding and conflict perceptions are asymmetrical; that is, one group can experience conflict while another does not. Other elements of group dynamics can affect crowding perceptions. For instance, people might be particularly sensitive to encountering large groups (Lime 1972). They might prefer to see many smaller groups in a wilderness setting than one very large group, even though they might see the same number of people (Stankey 1973; Pfister and Frenkel 1974).

Individuals highly committed to an activity can have a more strongly defined sense of appropriate behavior. This is reinforced in group settings to intensify perceptions of conflict with others' behavior (Driver and Bassett 1975; Gramann and Burdge 1981; West 1982b). Individuals can reinforce their own sense of commitment and belonging to a given social group by acting out perceptions of conflict of others. Thus, the group might not only define norms of behavior, but might channel the perceptions of participants toward the conflict, thereby catalyzing more negative feelings than would otherwise be there. The extreme expression of this dynamic is "mob effect."

Situational Factors.—Graefe and others (1984) noted that many factors influencing perceptions of crowding depend on where those perceptions occur and under what circumstances. For instance, people tend to be less sensitive to seeing others at the border of a wilderness than in the interior. In particular, the sensitivity to crowding appears to be heightened at the campsite. Stankey's studies report strong visitor preference for campsites screened from the sights and sounds of others (Burch and Wenger 1967; Stankey 1973). Lucas (1985) found a fairly strong association between visitor satisfaction and success in finding desired campsite solitude; eight out of 10 respondents preferred no other persons camped within sight or sound and about two-thirds reported they were able to find such conditions consistently. Heberlein and Dunwiddie (1979), in observing wilderness campsite selection in a portion of Wyoming's Bridger Wilderness, reported that experienced visitors were more likely to select sites farther from others and to select sites in zones containing the fewest other occupied sites. Further, the length of time that others are encountered might affect the sense of crowding (Titre and Mills 1982).

Designation of the area can have an effect. Shelby (1981a) suggested that persons in designated wilderness tend to be more sensitive to crowding than persons using undesignated but undeveloped recreation areas. This is likely due to the acceptance of definitions of the norms attributed to a certain recreation place (Lee 1972). It could also be a function of the tendency to assume that a designated area is of "higher quality," leading to higher expectations (Anderson 1980).

The person's relationship with the environment can also be a factor. If the individual has seen the environment change over time, with increasing numbers and diversity of use, this can result in a greater sensitivity to the presence of others (Driver and Bassett 1975; Vaske 1978). This is particularly the case if the person values the place highly and has a strong attachment to it (Jacob and Schreyer 1980).

In summary, numerous studies have focused on conflict and crowding in wilderness settings. Given the legislative mandate defining solitude as a key attribute of wilderness, this is not surprising. The research reveals considerable visitor concern with problems related to crowding and associated impacts.

Some reasonably well-agreed-on conceptions of appropriate interparty contact levels in wilderness settings are found in the literature. Most visitors prefer that daily contact levels not exceed two or three other parties. There appears to be even more consensus about appropriate use levels at campsites; there is a decided preference for no others camped within sight or sound. The argument has been made, in fact, that the ability of a wilderness to provide campsites that offer visitors this level of isolation might represent a "bottleneck" on the area's overall capacity (Stankey 1973).

The asymmetry in felt conflict between groups is also a consistent finding. The most obvious manifestation of this conflict is between groups using different methods of travel, such as hikers and horseback riders or canoeists and motorboaters. Persons traveling on foot or by paddling are highly sensitive to, and distressed by, contacts with persons traveling by other means, while this latter group shows less concern about the former. There appear to be some strong norms of appropriate behavior involved in this situation, ascribed to by the one group but not the other. The conflicts generated by these norms appear to be more critical than those brought about by encountering higher-than-preferred use levels.

The relationship between visitor satisfaction and encounter levels is complex. Following earlier work by Stankey (1973) that hypothesized declining satisfaction levels with rising levels of contact, empirical investigations of this relationship reported either no effect or, in many cases, an effect opposite to that hypothesized; that is, as use rose, so did satisfaction. Many of these studies, however, were conducted in nonwilderness settings where motives and expectations were not focused on outcomes related to solitude. Even in some wild river settings, characteristics of users (such as a large proportion of first-time visitors with ill-defined expectations about use) or situational characteristics (the excitement and thrill of running rapids, the noise of thundering water) likely diminish the significance of interparty contacts, further contributing to the conclusion that use levels have little effect on visitor satisfaction levels.

Increasingly, however, analyses have grown more sophisticated. Part of the explanation lies in recognizing the importance of different outcomes to visitors; for those to whom solitude is unimportant, rising contact probably has little significance. Conversely, for those who value solitude greatly, the presence of others can be a critical source of dissatisfaction. Moreover, we have come to understand that recreationists are able to employ a wide range of strategies to cope with situations they encounter so that they can continue to define their trip and experience in positive terms. Our understanding of the complexity of the concept of satisfaction continues to grow; the

lack of a statistical association between use level and satisfaction might reflect more the crude state of our ability to measure satisfaction than anything else.

Measures of the preferred types and levels of interparty encounters are useful information for managers concerned with establishing estimates of appropriate use. They reflect the kind of conditions visitors seek and, as such, provide managers with a basis for establishing objectives related to visitor experiences. The difficulty in measuring visitor satisfaction associated with different use levels should not be taken as an indication that the level and type of use visitors meet while in wilderness is not a matter of great concern to many of them.

SOME CONCLUDING REMARKS

As we review the studies covered in this paper, three broad conclusions can be made. First, there has been an evolution from a situational descriptive approach to the study of attitudes and behavior to one founded much more rigorously in theory. Many early investigations, although tied to general notions of perception or other organizing framework, lacked clear, explicit theoretical underpinnings (Stankey 1982). More recently, the theoretical rigor of investigations has increased significantly.

Second, over the period covered by this review, more sophisticated analytical procedures have been employed, moving from straightforward descriptive accounts, including frequency distributions and cross tabulations, to multivariate analyses, including a variety of cluster analytic techniques. As a result, the power and complexity of analyses have increased.

Finally, we see an increasing interest in examining attitudes and behavior within a social, as opposed to a psychological, context. Recreation behavior is a social behavior; it takes place typically within a group structure, and groups play a special role in motivating, sustaining, and giving meaning to such behavior. However, group influence on recreation behavior has only recently received the attention it warrants. It is our judgment that such a focus will provide added strength and meaning to efforts to understand recreation behavior.

Information about wilderness recreationists' attitudes and behavior is increasingly viewed as important to the planning and management process. There is growing recognition that experiences produced in wilderness settings are of parallel importance to the preservation of the ecological processes that characterize and shape such areas. If any single conclusion can be drawn from the substantial body of literature that we have reviewed, it is that people, users and nonusers alike, place a very high value on wilderness and are concerned with its future. Although many lack a technical understanding of wilderness management and might not possess a clear understanding of the subtleties, implications, and consequences of the various actions they may undertake, no one should underestimate the interest and concern they hold.

As we have suggested in several places, a major implication for managers is the need to provide this highly motivated clientele with accurate information from which they can make informed input. In many instances, it is clear that people do not possess the level of information they desire or need to make such input, but it is just as clear that they desire a role in the decision process and that the views they hold about management are of increasing importance in making those decisions.

Here is where research has an important role and obligation. If policy decisions about the management of wilderness are going to be made with public input as one critical element, those making such decisions have to be assured that the base of information about that public input is sound and reliable. Managers have as much reason to be concerned with the concepts of validity and reliability as scientists. There is often a point of conflict between the researcher and the manager on this matter. The manager sees the research worker's concern with the trappings of science—sample design, tests of significance, and so on—as clutter that holds up the delivery of the answer. The researcher, on the other hand, views the demands of the managers as another contaminant to be dealt with in the conduct of good science. The end result is often dissatisfaction on the part of both parties.

But as Shelby (1981b) has noted, both parties have important obligations in the process of integrating research findings into the management process. Chief among these obligations are the need to maintain an interactive environment where concerns can be expressed, to carefully define how research findings can and will be used, and to recognize that the development of a good information base from which sound decisions can be made requires time, money, and effort. We might also add that research findings, by themselves, seldom provide straightforward answers to the questions that face managers (Stankey 1979a). Such findings do, however, provide information that bears on these questions. It is in the interaction and dialogue that must accompany such applied research that both the limitations and opportunities inherent in the data can be drawn out.

As we look to the future and the needs for further research on attitudes and behavior, several issues seem apparent, some methodological, some substantive. Certainly one major area requiring attention is the need for longitudinal research designs that provide a sound basis for trend analysis. Such analyses could help identify major changes in client groups, tastes, and preferences that would serve as critical input into the revisions of management planning documents as well as provide important insight into how the image and meaning of wilderness are changing over time.

It is important that more work look at the role and meaning of wilderness in contemporary society, a perspective that extends beyond that held by the user. Users are only temporary tenants in the wilderness; however, such areas remain the property of society forever. The historical analysis pointed to the tremendous shift in societal attitude toward wilderness that has occurred in the past century; our review of attitudes toward management suggested some large changes have occurred in just the past 20 years. There seems little reason to presume this cultural evolution will not continue. We need to consider ways to monitor systematically such society-wide changes in perception.

We see a need for continuing work directed toward development of better ways to promote sensitive manage-

ment systems in wilderness, techniques that ensure protection of the wilderness experience at the same time they ensure adequate protection of fragile wilderness ecosystems. Influences on behavior that correct depreciative acts in subtle yet effective ways need to be ascertained. We are particularly concerned with how information can better serve the needs of both manager and user.

It is clear that relatively well-defined rules of appropriate conduct do emerge—norms that provide a framework of appropriate behavior. How do these norms develop; how are they communicated, internalized, and reinforced; and what forces lead them to change? To what extent can managers utilize such internalized forms of behavior control to achieve area objectives? In particular, are there ways in which such norms can be utilized as the basis of standards designed to ensure maintenance of wilderness quality?

We see a need to obtain a better grasp of how wilderness recreationists make decisions and what factors influence those decisions. What role, for example, does information about social and site attributes play in the decision process? What are the key attributes of wilderness settings that influence visitor selection of sites and their subsequent satisfaction? What group influences operate to shape individual decisions? How are the images that people hold of wilderness formed, how do those images affect their decisions about the use of such areas, and to what extent can those images be altered in a manner compatible with wilderness preservation while respecting the individual's freedom of choice?

Studies of wilderness visitors reveal their great adaptability to changing conditions and their capacity to achieve satisfactory experiences in response to these changes. Yet, just as clearly, visitors hold well-defined preferences for certain conditions, such as levels of encounters with others. There is a need to better understand this adaptive process and to clarify the relationship between preferred states and those considered tolerable. This range of acceptability could serve a particularly useful purpose in prescribing management guidelines.

Science often seems concerned with being innovative, but there are strong reasons to encourage replicative research projects involving repetitions both in time and over space. The trend study by Lucas (1985) provides a unique opportunity to look at the changes occurring in one area over the span of a decade; such studies done elsewhere would be similarly beneficial. Many of the studies of attitudes and behavior, like many ecological studies, have been conducted in the Western United States. There is a need to replicate these studies elsewhere to determine the extent to which the patterns involved are universal and shared or unique and idiosyncratic. There is particularly a need for improved consistency in such replicative research and to search for patterns of generalization, especially in motive clustering and site attribute preference research.

The continuing issue of how well attitudes predict behavior remains with us. Many of the behaviors with which we are concerned and the behavioral influences involved are difficult to measure. Surveys of attitudes and other dispositions such as preferences and expectations are relatively more easily conducted. But if such measures have weak reliability in predicting behavior, there might be little reason to conduct them. Improved models of the behavior-attitude linkage are needed.

We have noted the generally atheoretic nature of much of the previous wilderness research. There remains a continuing need for theory building and testing. Yet it is important to recognize that it is unlikely there is any single theory most appropriate for the study of wilderness attitudes and behavior or, indeed, that there is any theoretical perspective applicable to wilderness as such. The study of the recreational use of wilderness could be undertaken at a variety of differing levels of analysis, ranging from general human behavior, leisure behavior, outdoor recreation behavior, resource-based recreation behavior, to wilderness recreation behavior. The appropriate and most useful theoretical orientation likely changes as one moves from one level of analysis to another. What, if any, is the most appropriate level of analysis?

Since European settlement of North America, America's attitudes toward, and behavior with regard to, wilderness have undergone many changes, from hostility and exploitation to wonder and enjoyment. Now as the period of major expansion of the National Wilderness Preservation System begins to reach its latter stages, it is more important than ever that we better understand our Nation's attitudes and behavior so that we might better learn to preserve these treasured areas.

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WILDERNESS BENEFITS: A STATE-OF-KNOWLEDGE REVIEW

B. L. Driver, Roderick Nash, and Glenn Haas

ABSTRACT

Describes need for more objective information on wilderness benefits, especially as a base for formulating a sounder wilderness philosophy. Drawing on knowledge from the scientific and nonscientific literature on wilderness benefits, a taxonomy is presented that classifies benefits as personal, social, and intrinsic. Knowledge about each class and subclass within the taxonomy is considered. It is emphasized that most knowledge about benefits is based on introspective appraisals of benefits inferred from human preference studies. Closes with a discussion of which of the benefits are most, and which are least, central to development of a sounder wilderness philosophy.

INTRODUCTION

Since passage of the Wilderness Act (PL 88-577) in 1964, about 89 million acres (227 million hectares) have been included in the National Wilderness Preservation System in the United States. Even larger acreages of undesignated wilderness exist in the United States and in other countries. These designated and undesignated wildernesses are managed because of the benefits they provide. This paper describes what is known about those benefits. It says nothing about costs, a discussion also needed for a balanced understanding of wilderness values.

Why Understand Benefits?

Knowledge about its benefits can help managers and proponents of wilderness in several ways:

Enhance Rationality of Resource Allocation Decisions.—Public policymakers need to compare the benefits and costs of alternative uses of wilderness resources. These comparisons, which include but go beyond economic measures of benefits, have grown in importance as demands on public resources have increased and broadened. Among other things, information on wilderness benefits would help prevent making allocations for short-term gains that cause undesired long-term effects.

Help Promote Optimal Management.—Once basic public resources have been allocated to wilderness, information on benefits would improve the ability of the resource planners and managers to define clear management objectives and prescriptions and then establish more explicit standards and guidelines for meeting those objectives. The management objectives should be developed to maximize net wilderness benefits, including those accruing to the appreciative off-site users.

Identify Substitutes.—The information on benefits would also identify more clearly those benefits unique to wilderness, those that are not unique but highly preferred to be realized from wilderness, and those that can be obtained from alternative resources with no preference that they be realized from wilderness. Such information is needed to identify substitutes for wilderness uses.

Guide User Fees.—A basic tenet of public finance is that the beneficiaries should pay their fair share of the costs of providing a particular public good or service. Information on wilderness benefits would make it possible to better identify what type and proportion of those benefits accrue primarily to individuals (and to which types of individuals), to society at large, and to future generations. Thus, a better "multiple-part" pricing system could be designed under which different types of beneficiaries either pay user fees or are subsidized by public taxation.

Facilitate Additional Research.—Given that research is a building process, an understanding of the current state of knowledge about wilderness benefits would nurture additional hypotheses, research, and knowledge. In addition, the information on benefits could be used to cross-check the validity of techniques being used to measure wilderness values, such as the contingent-valuation method (Walsh and others 1984) for estimating users' willingness to pay for wilderness-related benefits.

Enhance Consumer and Voter Sovereignty.—Information on the benefits would facilitate more rational consumer and voter behavior with respect to wilderness use and protection.

Advance Professions.—Because the most fundamental feature of any profession is its body of knowledge, systematic information about wilderness benefits would advance the professions of those working on wilderness preservation, policymaking, planning, management, and valuation, and increase the personal pride of these professionals. Although subtle, such shifts could have profound impacts on promoting sounder wilderness policies and management.

Promote a Wilderness Philosophy.—An understanding of wilderness benefits is necessary to develop what we call a wilderness philosophy. This term signifies the underlying principles or values upon which the defense of wilderness can be built.

A sound and widely accepted philosophy has been notably absent in the American preservation movement, which can be characterized largely by a series of highly subjective defenses of particular places: "Save Hetch Hetchy," "Save the Redwoods," "Save Grand Canyon." If

someone asked, "Why?", the reply was that it is the Grand Canyon, for Pete's sake! But still, why save it, why keep it wild? "Well," the preservationists traditionally retorted, "we like it wild." But their interrogator might persist, again, with the question, "Why?" The point is that wilderness appreciation has been a creed, a faith, something that was almost sullied by analysis and discussion, something you felt in your bones. But that is not good enough, especially when the existence of wilderness is challenged by deep-rooted materialism.

There is a need for a systematic articulation of wilderness benefits based not only on objective scientific research but also on historical fact and contemporary experience, including nonhuman values. This is what we mean by a philosophy of wilderness. It must lie behind the defense of particular wild places like the philosophy of human dignity and freedom lies behind the protest of racist policies. Philosophers have spent 24 centuries, since the Greek democracies, setting forth a philosophy of liberty. So, when Thomas Jefferson declared that all men were created equal, when Lincoln emancipated the slaves, or when contemporary Americans say that South Africa's apartheid is wrong, few ask why. But the value or benefit of wilderness is not nearly so well established. A major purpose of this paper is to summarize the best contemporary thinking on this subject in the hope that it will advance the articulation of a wilderness philosophy.

Definitions

Wilderness.—As Nash (1982) argues in "Wilderness and The American Mind," wilderness is a perceived reality—a state of mind. It is not just a particular collection of natural objects; it is a collection of feelings about those objects. Thus, wilderness has more to do with the contour lines in our heads than with those on maps; it exists, in other words, in the eye of the beholder. And there are a lot of beholders, which makes for a wide variety of definitions and management opinions. Thus, any attempt at a definition is arbitrary. For our purposes, wilderness will include, but not be limited to, land areas in the United States designated under the Wilderness Act. Included will be relatively large areas that are neither easily accessible nor frequently used by motorized vehicles, where opportunities exist for primitive types of recreation, and past and current human activities are not readily noticeable. The concepts of spaciousness and wildness are central, because that is what Americans have traditionally had in mind when they thought about wilderness.

Benefits.—Modern dictionaries generally define a benefit as a facilitator of an advantageous condition or state; for example, "something that guards, aids or promotes well-being"; "anything that enhances well-being"; "anything that is advantageous or for the good of a person or thing." According to these definitions, an aspirin is a benefit to someone with a headache, and a wilderness is a benefit to a grizzly bear. These things as facilitators can be called benefits even though the resulting advantageous conditions have not been specified. This definitional approach, therefore, does not disclose how wildernesses benefit humans and other organisms, which is the purpose of this paper. To serve that purpose, the dictionary definitions were extended to define a benefit as a specific advantageous condition, not the facilitator of such. Thus, the word "benefit" is used to denote a desirable change of state; it is a specific improved condition or state of an individual or a group of individuals, of a society, or even of nonhuman organisms.

We modify the dictionary definition to include also as a benefit the prevention of a worse state from happening. For example, if people are kept from harm, they have benefited or are in a better condition than if harmed, even if no improvement was made over the condition that existed before the danger emerged. Our definition focuses on advantageous consequences (for example, meeting held beliefs about stewardship responsibilities, increased appreciation of human-physical environmental interdependencies, medical advances from maintenance of species diversity) of such actions as preservation of wilderness, thinking about wilderness, and visiting wilderness. Our concept need not be anthropocentric; benefits to nonhuman organisms are included (Rolston 1982, 1985a, 1985b). It includes the economists' measures of the willingness of individuals to pay for the wilderness-related goods and services that provide the benefits on which those economic values are based.

Implicit in our definition of a benefit, as an improvement in a state, is the need to define why a change in a particular condition or state is beneficial or not. What constitutes an improvement, though, and who is to say? The judgments required to answer these questions are based on human beliefs and values, which vary from one context to another (Brown 1984); what is beneficial to one person at one time is not at another, and what is viewed as a benefit to one person or group might be viewed as a cost to another. Where possible, we have tried to define the benefits discussed. For example, the possibility of discovering a new medicine is one value of maintaining species diversity. However, it was frequently impossible to do more than list the benefit, or "define" it at face value. The reported spiritual benefits of wilderness are a good example.

The contextual difficulty of specifying wilderness benefits was also accompanied by what we will call "causative" and "inferential" problems. Frequently, benefits are viewed as synonymous with conditions that can cause the benefits to occur, and it is frequently easier to specify those conditions than the benefits. For example, opportunities for solitude, enjoyment of primitive types of outdoor recreation, and preservation of ecosystems and germ plasm are often called benefits of designated wilderness. These are not benefits as we have defined them but things that can lead to improved states, which might be replenished adaptive abilities, advancement of human health from discovery of a new drug, or increased mental satisfaction realized from knowing that good stewardship is being exercised.

The inferential problem arises from the need to differentiate subjectively defined desires for wilderness attributes from behavioral-change measures of wilderness benefits. We have no qualms with the notion that preferences guide behavior and that people generally behave reasonably and in their best interest. However, for the purposes of this paper we can interpret wilderness-related preferences only

as perceived benefits, and then only if the preferences are for clearly defined improved states. For example, expressed preferences for opportunities to nurture family kinship, to exercise, or to escape a demanding job suggest that different benefits are perceived by the users. It cannot be assumed, though, that any behavioral-change measures made later would disclose greater family solidarity, improved physiological functioning, or behaviors reflecting increased productivity at work. This made our assignment difficult; although we would rather discuss wilderness-caused beneficial changes in behavior, virtually all studies from which inferences can be drawn about particular types of wilderness benefits have employed introspective reports that appraised the users' preferences for benefit-implying conditions. Very few studies analyzed changes in behavior that were categorized as beneficial by the researcher. Also, few of the economic studies that quantify willingnesses to pay to derive wilderness-related benefits have attempted to describe specific types of benefits being valued. Given that scores of studies have been conducted using subjective appraisals from which inferences to benefits can be made, much of what we report is drawn from that research.

HISTORY OF INQUIRY ABOUT WILDERNESS BENEFITS

Before the 1960's, the wilderness literature was dominated by "classical" writings (Gilligan 1955; Leopold 1921; Marshall 1930; Saylor 1956-57; Wagar 1940; Zahnizer 1955). These writings led to Congressional establishment of the National Wilderness Preservation System and prompted the initiation of wilderness research.

The emphasis of most early research was on the sociological and managerial aspects of wilderness. Those studies focused on management practices and user characteristics, such as densities, travel patterns, conflicts, and use rates (Brandborg 1963; Bultena and others 1961; Frissell and Duncan 1965; King 1965; LaPage 1963; Lucas 1963, 1964a, 1964b; Merriam 1964; Mueller and Gurin 1962; Stone and Taves 1958; Wagar 1963, 1964; Wenger 1964). Only a few studies considered benefits (Burch 1966; Etzkorn 1964; Outdoor Recreation Resources Review Commission 1962).

Toward the end of the 1960's, studies of user attitudes, motivation, and satisfaction began to provide some research-based information about values of wilderness to on-site users from which inferences to benefits could be made (Catton 1971; Cheek 1972; Hendee and others 1968; Knopf and others 1973; Lucas 1964c; Shafer and Mietz 1969; Stankey 1973). About this time too, or slightly earlier, the Outward Bound and other wildland challenge programs grew in the United States, with several studies of benefits to self-development accompanying this growth (Burton 1981). Studies too had been made of summer youth camps, but few focused on wilderness (Burch 1977).

Since 1970, additional studies have been made of the therapeutic/healing benefits of wildland settings for clinical types of programs for problems such as juvenile delinquency and drug abuse (Levitt 1982). Many more attitude and motivation studies involving wilderness users were conducted, as were additional sociological and economic studies (Driver and Brown 1983; Dwyer and others 1977; Kelly 1974; Knopf 1982; LaPage and Ragain 1974; Lime 1971; Nash 1977; Peterson 1974).

The Wilderness Act and the "environmental movement" of the late 1960's gave impetus to more ecological impact studies (Frissell 1973) and studies concerning wildlife (Kellert 1979; Ream 1980). In addition, 1977 amendments to the Clean Air Act focused some attention on the benefits of maintaining air visibility over Class I areas, which includes many designated as wilderness (Fox and others 1979; Johnson and Haspel 1983).

Over time, as demands grew and broadened for different uses of public lands, the concepts of scarcity and economic efficiency gained more prominence (Clawson and Knetsch 1966; Loomis and others 1984; McConnell 1983; Mills and others 1980). This trend stimulated a growing number of studies of the economic benefits of preservation actions (Bishop 1982; Randall and Stoll 1983; Walsh and others 1984).

In summary, little research has attempted to measure beneficial changes in behavior that can be attributed to wilderness preservation and use. However, much research has solicited users' opinions about wilderness values from which inferences to benefits can be made. Most of that research has occurred since 1970.

APPROACH

Delimitations

The lack of systematic research that focuses directly on wilderness benefits limits the state of knowledge in several ways that should be made explicit. Briefly, those delimitations are:

1. Some types of benefits have probably not yet been identified.
2. Almost all of the studies that have attempted to define particular types of benefits have used self-reports in questionnaires that measured users' subjective appraisals of benefits, or benefit-implying preferences, instead of measuring actual behavioral changes defined by the scientists as constituting particular types of benefits. It is impossible to state accurately the magnitude of any benefits inferred from this "perceived benefits" research that used introspective reports. The behavioral-based (for example, travel-cost methods) economic measures of recreation benefits do not specify particular types of benefits desired but instead value a particular recreation opportunity, site, or attribute of an opportunity.
3. Some of the research has not been sufficiently systematic; too frequently sample sizes were small and nonrandom, nonresponse bias was not accounted for, control groups were not used, longitudinal studies to trace responses over time were too few, and some scientists generalized too broadly from their data and even imposed their own values in their conclusions.
4. Very little study has been made of the benefits obtained by the off-site (vicarious or appreciative) users, whose numbers greatly exceed the on-site users.
5. Some of the research was not limited to wilderness-related phenomena but overlapped with nonwilderness uses in ways that were difficult to differentiate.

6. It was frequently impossible to determine if the benefits reported or inferred were uniquely attributable to wilderness.

Most of these delimitations can be explained as resulting from inadequate funds and the extreme complexity of the research. We will expand on No. 6 because it influenced our interpretation of knowledge about wilderness benefits.

As we see it, there are three categories of benefits provided by wilderness:

1. Benefits that can be obtained only from wilderness.
2. Benefits that can be obtained from both wilderness and nonwilderness, but for which wilderness is strongly preferred as the source.
3. Benefits that can be obtained from both wilderness and nonwilderness, but for which no strong preferences exist for wilderness as the source.

Three questions with respect to this listing and relevant to the purpose of this paper must be kept separate because the answers mean different things. First, can each class of benefits be attributed to wilderness? The answer is yes, if wilderness provides them, even though nonwilderness areas can provide types 2 and 3 and perhaps do so more cost effectively. Second, can each type of benefit be uniquely attributed to wilderness? No, only type 1 can. Third, should wilderness be maintained to provide each type of benefit? The answer is not up to us. If type 1 benefits are to be realized, they must be derived from wilderness. If enough people in a pluralistic republic desire type 2 benefits strongly enough, they will be provided by wilderness. Also, if these preferences are quite strong in the minds of those beneficiaries, the type 2 benefits might be as wilderness dependent as type 1. Because all three types of benefits can be attributed to wilderness, even though not uniquely so, we included each in our review of knowledge about wilderness benefits. We will consider the wilderness dependency of particular types of benefits in the last section of the paper.

Taxonomy of Benefits

The categories of benefits derived from a review of the scientific and nonscientific literature have been organized into a taxonomy (table 1) having three major categories: personal benefits, social benefits, and inherent/intrinsic benefits. Personal benefits are those that can be realized by individuals whether or not they can be aggregated across individuals. Social benefits are those realized by individuals collectively that accrue to society or subcultures of society. The third class, inherent or intrinsic benefits, are those benefits that accrue to plants and animals from wilderness preservation whether or not humans benefit currently or in the future from those benefits (Rolston 1982; Callicott 1985). The lengthy list of benefits in table 1 could imply a larger body of knowledge than exists. That risk accompanied our attempt to be comprehensive.

PERSONAL BENEFITS

Two types of users of wilderness and other natural areas are frequently identified in the literature, the on-site visitor and the off-site user. The latter either uses the resources from a distance vicariously or appreciatively according to a variety of held values, or realizes personal gains from the off-site use of wilderness-related commodities such as minerals, increased quantities or quality of water, range forage, and tourism income.

Both types of users receive personal benefits from wilderness resources. In fact, if personal benefits accrued only to on-site users, there would be little support for a wilderness preservation system simply because of the low percentage of the United States population that actively visits (or has visited) designated wilderness areas. This percentage has been estimated to range from 6 to 15 percent; whereas several surveys show 60 to 95 percent of the populations studied support the idea of wilderness preservation and have expressed willingness to be taxed for its support (Opinion Research Corporation 1977; Wallwork 1984; Young and Fry 1979; Young 1980). Nevertheless, most of the research on the personal benefits of wilderness has studied the on-site user, with little focusing on the vastly larger number of off-site users who are the predominant supporters of wilderness (especially designated wilderness).

Developmental Benefits

This category of personal benefits refers to any desirable changes in on-site wilderness users' self-concepts, self-actualization, or skill development and application.

Studies of Self-Concept Benefits From Sponsored Programs.—Two types of studies have addressed perceived changes in the self-concepts of wilderness users—research on participants in sponsored wildland challenge/adventure programs and research on general wilderness users. Each will be considered separately. Use of wilderness as "training grounds" by organized programs, such as Outward Bound and the National Outdoor Leadership School, has grown rapidly. Burton (1981) estimated that there are more than 300 such programs including those for juvenile delinquents, psychiatric patients, corporate managers, the military services, and educators.

The wildland challenge programs have received extensive study and several excellent review articles are available. Ewert (1983) focused on self-concept in his review of over 50 studies, and he critiqued them separately by types of programs, such as Outward Bound, survival training, and education programs utilizing outdoor adventure activities. Burton (1981), as a doctoral dissertation study at Rutgers, critically analyzed 72 studies of Outward Bound-type programs. Because these two reviewers agree closely in their summary interpretations, as we did too following a random review of several of the studies they analyzed, we will report the results of Burton's more comprehensive analysis.

Burton pointed out that 59 different evaluation instruments were used in the 72 studies to make a total of 115 measurements of 41 different outcome variables. These benefit-implying variables ranged from self-concept—through locus of control, anxiety, and self-actualization—to academic achievement and acceptance of others. Burton identified several methodological deficiencies with many of the studies (small sample sizes, failure to do follow-up studies, no or unmatched control groups, use of unstand-

Table 1.—Taxonomy of wilderness benefits

I. Personal benefits (accruing primarily to individuals and might or might not benefit society at large)
  A. Developmental (desired changes in self-concepts and skills)
    1. Self-concept
    2. Self-actualization
    3. Skill development
  B. Therapeutic/healing
    1. Clinical
    2. Nonclinical (stress mediation/coping)
  C. Physical health
  D. Self-sufficiency
  E. Social identity (development/maintenance of desired social relations with family and others)
  F. Educational
  G. Spiritual
  H. Esthetic/creativity
  I. Symbolic (benefits from options to realize that actions are being taken in support of preservation-related beliefs)
    1. Resource stewardship
    2. Anti-anthropocentricism/moralistic
    3. Option demands
    4. Other
  J. Other personal wilderness recreation-related benefits
  K. Commodity-related (benefits to individuals from goods produced from wilderness such as those related to water and to grazing by domestic animals)
  L. Nurturance

II. Social benefits (accruing across individuals to society collectively or to large segments of society)
  A. Aggregate personal benefits
  B. Spinoff benefits
  C. Historical cultural benefits
  D. Preservation-related benefits
    1. Representative ecosystems
    2. Species diversity
    3. Air visibility
    4. Unique landforms, including areas of outstanding scenic beauty
    5. Historic sites
    6. Educational values
    7. Scientific laboratory
    8. Stewardship (options for future generations)
  E. Quality of life
  F. Commodity uses (water, minerals, grazing, etc.)
  G. Economic benefits
    1. National economic development
    2. Local/regional economic development

III. Inherent/intrinsic (benefits to nonhuman organisms)

ardized tests, and no or insufficient statistical testing of score differences) and grouped the studies into All Studies (72) and Valid Studies (19). Burton then analyzed the two groups and reported the following percentage distribution of results:

Results	Distribution (All studies, 72)	Distribution (Valid studies, 19)
	Percent	*Percent*
Mostly positive	40	21
Some positive	36	47
No change	18	32
Negative	3	0

These findings indicate that, although more positive results were reported when the studies with "invalid" designs were included, about 70 percent of the studies with valid designs reported at least some beneficial change. Self-concept was the benefit-implying variable reported most frequently as having the most positive results in both categories of studies, in part because that variable was measured most frequently by the instruments employed. Burton stated that one of the most startling findings was that, across all studies reviewed, only three reported negative findings.

Burton's conclusions are that "it appears that Outward Bound-type programs do have positive effects. . . most substantial in the area of self-perception (self-concept, personality, locus of control and self-assertion)" even though few behavioral correlates were found. Burton proposes that it might take more time than the follow-up studies permitted for these behavioral changes to occur, as suggested by two studies that made follow-up measurements 5 years after the programs ended. Thus, beneficial behavior changes might have been greatest after a period of time not covered by most of the studies.

Studies of Self-Concept Benefits From General Wilderness Use.—Although no studies were found that

Table 2.—Mean scores[1] and their ranks (in parentheses) of responses to 16 wilderness recreation experience preference domains by users of eight designated wildernesses, four undesignated wildernesses, and three contrasting nonwilderness areas, with States in which located

Experience preference domains	Designated wildernesses: Weminuche (CO) (N = 313)	Maroon Bells(CO) (N = 268)	Flattops (CO) (N = 135)	Eagles Nest(CO) (N = 271)	Rawah (CO) (N = 212)	Linville Gorge(NC) (N = 249)	Shining Rock(NC) (N = 297)	Joyce Kilmer(NC) (N = 80)
1. Enjoy nature	1.5(1)	1.5(1)	1.5(1)	1.5(1)	1.7(1)	1.5(1)	1.6(1)	1.4(1)
2. Physical fitness	2.4(4)	2.0(2)	2.5(5)	2.3(2)	2.3(3)	2.1(2)	2.2(2)	1.8(2)
3. Reduce tensions	2.1(2)	2.3(4)	2.1(2)	2.4(3)	2.2(2)	2.3(3)	2.3(3)	2.1(3)
4. Escape noise/crowds	2.2(3)	2.2(3)	2.2(3)	2.4(3)	2.2(2)	2.3(3)	2.3(3)	2.2(4)
5. Outdoor learning	2.1(2)	2.4(5)	2.4(4)	2.5(4)	2.2(2)	2.3(3)	2.4(4)	2.2(4)
6. Sharing similar values	2.8(5)	2.9(6)	3.2(8)	2.8(4)	2.8(4)	2.7(4)	2.9(5)	2.7(6)
7. Independence	3.1(7)	2.9(6)	2.8(7)	3.3(7)	3.0(6)	3.0(7)	3.0(6)	3.0(8)
8. Family kinship	3.0(6)	3.0(7)	2.6(6)	3.2(6)	2.9(5)	3.4(9)	3.1(7)	3.0(8)
9. Introspection/spiritual	3.5(8)	3.1(8)	3.3(9)	3.7(8)	3.5(7)	2.8(5)	2.9(5)	2.6(5)
10. Considerate people	3.6(9)	3.4(9)	3.2(8)	3.8(9)	3.7(8)	3.0(7)	3.3(8)	2.8(7)
11. Achievement/stimulation	3.9(11)	3.1(8)	3.4(10)	4.0(11)	3.9(10)	2.9(6)	3.1(7)	3.0(8)
12. Physical rest	3.8(10)	4.3(10)	2.5(5)	3.9(10)	3.9(10)	3.2(8)	3.3(8)	3.4(9)
13. Teach/lead others	3.7(10)	4.3(10)	3.5(11)	3.9(10)	3.8(9)	3.6(10)	3.7(9)	3.9(10)
14. Risk taking	4.7(12)	4.8(12)	4.8(13)	4.6(12)	4.8(10)	4.1(11)	4.5(10)	4.6(12)
15. Risk reduction	4.8(13)	4.7(11)	4.7(12)	4.7(13)	4.8(11)	4.7(13)	4.7(11)	4.7(13)
16. Meet new people	5.6(14)	5.3(13)	5.5(14)	5.5(14)	5.8(12)	4.6(12)	4.5(10)	4.5(11)

Experience preference domains	Undesignated wildernesses: Indian Peaks(CO) (N = 101)	Vermont (VT) (N = 415)	Commanche (CO) (N = 424)	Shoshone (WY) (N = 165)	Nonwilderness areas: Little Sahara(UT) (N = 421)	Arkansas River(CO) (N = 442)	Lake Shelby-ville(IL) (N = 1,567)
1. Enjoy nature	1.8(1)	2.5(2)	1.7(1)	1.9(1)	2.4(4)	1.7(1)	3.1(2)
2. Physical fitness	2.8(4)	2.7(4)	2.4(2)	2.2(3)	2.2(3)	2.3(4)	3.1(2)
3. Reduce tensions	1.9(2)	1.9(1)	2.4(2)	2.0(2)	2.7(5)	2.2(3)	3.3(4)
4. Escape noise/crowds	2.8(4)	2.8(5)	2.5(3)	2.0(2)	3.1(9)	2.1(2)	3.3(4)
5. Outdoor learning	2.4(3)	2.5(3)	2.5(3)	2.2(3)	2.9(8)	2.3(4)	3.8(6)
6. Sharing similar values	3.3(6)	3.0(7)	3.5(7)	3.1(7)	1.2(1)	2.3(4)	3.1(2)
7. Independence	3.2(5)	2.9(6)	3.2(4)	3.1(7)	2.7(6)	2.7(5)	3.7(5)
8. Family kinship	3.4(7)	3.6(9)	3.6(8)	2.5(4)	2.1(2)	2.1(2)	3.2(3)
9. Introspection/spiritual	3.3(6)	3.2(8)	3.4(6)	2.6(5)	3.5(12)	3.5(8)	4.1(8)
10. Considerate people	3.1(4)	—	3.3(5)	3.0(6)	—	—	4.8(10)
11. Achievement/stimulation	3.6(8)	3.3(9)	3.8(9)	3.1(8)	2.8(7)	3.1(6)	4.2(9)
12. Physical rest	3.1(4)	5.0(11)	3.4(6)	3.3(9)	3.2(10)	2.1(2)	3.0(1)
13. Teach/lead others	4.2(9)	—	4.1(10)	3.9(10)	3.6(13)	3.1(6)	5.2(11)
14. Risk taking	4.6(10)	3.2(8)	5.1(13)	2.2(3)	2.2(3)	2.2(3)	5.3(12)
15. Risk reduction	4.7(11)	—	4.5(11)	4.9(11)	3.3(11)	3.4(7)	—
16. Meet new people	5.1(12)	4.5(10)	4.9(12)	4.9(11)	3.5(12)	4.0(9)	4.0(7)

[1]Ratings were made on the following 9-point response format (with numerical codes used to compute means): Adds (to satisfaction): most strongly (1), strongly (2), moderately (3), a little (4), neither adds nor detracts (5); Detracts: a little (6), moderately (7), strongly (8), most strongly (9). Coefficients of variation were 20-50 percent of the means.

applied standardized instruments for measuring changes in self-perceptions of general wilderness users not participating in Outward Bound-type programs, quite a few studies have used various measures of the perceived importance that users assign to skill development, self-testing, and being challenged physically as reasons for participating in particular wilderness recreation activities. Table 2 shows the results of studies of users of eight designated wildernesses, four undesignated wildernesses (at the time of the studies in 1977 and 1978), and three contrasting nonwilderness areas. That table gives mean scores and rank orders of mean scores for 16 different recreation experience preference domains using psychometric instruments (Recreation Experience Preference scales) developed by Driver and his associates, notably Richard Knopf, Perry Brown, and Glenn Haas. (For a discussion of development and use of the scales, see Driver 1976; Driver and Cooksey 1980; Driver and Knopf 1976; and Haas and others 1980.)

The experience domains shown in table 2 tap more general recreation experience preferences than did the 38 more specific scales (shown in table 3) making up those domains. For each wilderness area studied, systematic samples of recreationists were asked after participation to rate how much each type of experience would either add to or detract from their level of satisfaction with their

visit to a particular area for their chosen type of recreation activity. Ratings were made to the nine-point response format described in the footnote to table 2. Only a small amount of the data given in table 2 has been reported previously by Brown and Haas (1980); Haas and others (1980); and Roggenbuck (1980). For that reason those data are summarized in this state-of-knowledge paper, without statistical testing of differences between areas.

Table 2 shows that although pursuit of other benefit-implying psychological goals ranked higher in overall importance, scale items within domain 11 (achievement/stimulation), which tapped preferences related to self-concept ("development of skills and abilities" and "gaining a sense of self-confidence"), were rated as being a little to moderately important ($\bar{x}=3.0$) to the visitors to all the areas studied, including the nonwilderness areas. Other studies of wilderness users support these results (Ditton 1981; Peterson 1971; Schreyer and Nielsen 1978a). Thus, wilderness recreationists perceive that developing skills is a desired benefit of their wilderness recreation activities. Of course, the importance of these self-concept-related benefits varies from one type of user to another.

Self-Actualization.—Maslow (1969) conceived of self-actualized individuals as being those who operate at the peak of their "needs hierarchy," which is considered by many supporters of that idea as the ideal psychological state, where effective functioning is optimal. Drawing on this concept, Scott (1974, p. 236) hypothesized that "wilderness experiences are more likely to foster self-actualization and the occurrence of peak experiences than outdoor activity in more degraded environments." Young and Crandall (1984) tested this hypothesis in two studies. One (1984) showed small, but statistically significant ($P \leqslant 0.03$) differences (on Shostrom's [1974] Personality Orientation Inventory) in self-actualization between Illinois users of the Boundary Waters Canoe Area (BWCA) and nonusers of wilderness. There were no differences between those who used the BWCA frequently in 1976 and those who used it less frequently. Since these results were only for the period of 1976, Young and Crandall (1986) conducted a second and longitudinal study of BWCA users, with questionnaires administered in 1979 and 1984. They report, "Self-actualization scores were significantly higher in 1984 than in 1979. In comparing the more active users in the panel with the less active, self-actualization increased for both groups but significantly more for the active users." They conclude that the results "suggest that wilderness use may cause increases in self-actualization either directly or through moderating variables."

Skill Development.—In addition to development of improved self-concepts and enhanced abilities for self-actualization, the recreation experience preference studies, and other introspective studies, indicate that wildernesses are used for skill development and competence testing—the labels given two scales in domain 11 (achievement/stimulation) in table 3. Table 2 shows that the values

Table 3.—Recreation experience preference scales making up the recreation experience preference domains abbreviated in table 2

1. Enjoy nature
   A. Scenery
   B. General nature experience
2. Physical fitness[1]
3. Reduce tension
   A. Tension release
   B. Slow down mentally
   C. Escape role overloads
   D. Escape daily routine
4. Escape noise and crowds
   A. Tranquility/solitude
   B. Privacy
   C. Escape crowds
   D. Escape noise
5. Outdoor learning
   A. General learning
   B. Exploration
   C. Learn geography of area
   D. Learn about nature
6. Share similar values
   A. Be with friends
   B. Be with people having similar values
7. Independence
   A. Independence
   B. Autonomy
   C. Being in control
8. Family kinship[1]
9. Introspection
   A. Spiritual
   B. Personal values
10. Be with considerate people[1]
11. Achievement/stimulation
    A. Reinforcing self-confidence
    B. Social recognition
    C. Skill development
    D. Competence testing
    E. Seeking excitement
12. Physical rest[1]
13. Teach/lead others
    A. Teaching/sharing skills
    B. Leading others
14. Risk taking[1]
15. Risk reduction
    A. Risk moderation
    B. Risk prevention
16. Meet new people
    A. Meet new people
    B. Observe new people

[1]These domains have only one scale, with the same title as the domain.

tapped by that domain added moderately to the overall experience of most of the wilderness recreationists studied in the 12 locations shown. These overall mean scores disguise the fact that skill development and competence testing are frequently of even greater importance to particular subgroups or market segments (Manfredo and others 1978).

Therapeutic/Healing Benefits

Clinical Studies.—Just as for the self-concept benefits, programs are sponsored to capture a variety of therapeutic benefits attributed to wilderness. Levitt (1982), in her overview of studies of "wilderness therapy," states that more than 100 such studies have been done to appraise the value of wilderness-related clinical programs in improving the effective performance of delinquents; in- and out-patients of psychiatric institutions, including emotionally disturbed children; drug abusers; and others having clinical problems. Levitt critically questions the research designs of the studies and apparently writes them all off as invalid. The design problems detected, in addition to some of the methodological ones raised for evaluation of Outward Bound-type programs, were lack of sufficient control of various extraneous and intervening variables and imprecise definition of wilderness given that many of the programs were not operated in wilderness settings.

Although we share the concern that tighter research designs are needed, our interpretation of the literature is a little more lenient and conforms more to the conclusions of the reviews by Barcus and Bergenson (1982) and by Gibson (1979). Specifically, the better designed studies show evidence of some therapeutic gains; patterns for recidivism across the studies are not clear, so no generalizations can be made other than that suggestions of reduced recidivism in different types of problematic behaviors appear frequently but not consistently. The most troublesome questions are whether these beneficial gains can be attributed to features of the wilderness or natural settings, to removal from institutional settings, or to the attention received from the counselors during the program.

Nonclinical Studies.—Many studies using self-reports indicate that the general public uses wilderness to gain therapeutic benefits. In more than a hundred studies in which the Recreation Experience Preference scales have been applied, including dozens of wild river studies by Lime and his associates (Knopf and Lime 1984), the themes of re-creation (coping temporarily with a variety of mental and physical stresses, physical rest, change of scene, etc.) always rank in the top, most highly valued reasons for engaging in all activities studied. Thus, various dimensions of stress reduction are pervasive motivators for most leisure pursuits (Driver 1976; Driver and Knopf 1976; Mandell and Marans 1972). Specific to wilderness, table 2 shows that the general experience preference domains 3 (reduce tensions) and 4 (escape noise and crowds) ranked second and fourth in importance (among the 16 preference domains measured) for users of all but one (Vermont) of the 12 designated and de facto wildernesses studied. Experience preference research suggests also that specific scales related to seeking tranquility, isolation, privacy, and solitude (with all its subdimensions [Hammitt 1982a, 1982b]) are the most dependent on wilderness settings, and in some instances rather uniquely so, especially for particular subgroups of users. Furthermore, Stephen and Rachel Kaplan have done creative and integrative work in defining the descriptive and predictive dimensions of what they call "restorative environments." Those dimensions include attributes such as tranquility, peace and silence, wholeness, and oneness that call primarily on involuntary rather than voluntary attention (Kaplan 1978; Kaplan and Talbot 1983).

Ulrich (1981) has reported studies showing that subjects, when viewing slides of natural (not necessarily wilderness) scenes, displayed higher physical manifestations (alpha brain wave and heart rate) of wakeful relaxation than when viewing slides of urban scenes. His 1984 article suggests that hospital patients recovering from surgery benefited more from window views of natural scenes than views of other scenes. He also has recently completed another study that used other physiological correlates of recovery from anxiety and stress (muscle tension, skin conductance, and pulse transit time, a noninvasive measure that correlates with blood pressure). It showed faster recovery by subjects viewing videotapes of natural scenes than those viewing urban scenes (Ulrich 1986). To be sure, conclusions from studies of natural versus urban areas should not carelessly be extended to wilderness, but neither should the studies go unnoticed.

Physical Health Benefits

Travel to and within wilderness areas generally requires some physical activity, and it is frequently extended and aerobic. Therefore, the physical health benefits attributed to physical activity (Buccola and Stone 1975) are at least partially contributed to by wilderness-related exercise even though such exercise could be attained in other than wilderness environments. Interestingly on that note though, desire to "exercise and for physical fitness" (domain 2) was generally rated second to fourth in importance among the 16 molar experience preference domains shown in table 2 for users of the 12 wildernesses studied. Many other studies of "motivations" of active wilderness recreationists also rank exercise and/or physical challenge as highly valued benefit-implying preferences (Brown 1981; Lee and others 1982; Schelhas 1979). Thus, although physical exercise can be obtained in nonwilderness environments, it is strongly preferred by—as well as required of—on-site users of wilderness areas. It should be noted that the recently incorporated Wilderness Medical Society (with a membership of 500 physicians across the United States) is directing its research toward the human physiological effects of recreating in wilderness-type areas.

Self-Sufficiency Benefits

Robert Marshall (1930) was a strong proponent of the argument that wilderness provides "opportunity for self-sufficiency." Thoreau, even earlier, touched on this theme in his awareness of the value of occasional reversions to the primitive, and he tested this during his stay at Walden Pond. More recently, authors such as Wagar (1940) and McAvoy and Dustin (1981) have echoed that theme. Strong inferences about these types of benefits can be

drawn too from the many studies (for example, Rossman and Ulehla 1977) that show self-testing, seeking adventure, and challenge are important psychological attributes of wilderness outings. That importance is especially great for particular "market segments" such as those participating in the sponsored Outward Bound-type and challenge-related therapeutic programs and participants in high skill-demanding activities in wilderness, like technical mountain climbing and orienteering (Manfredo and others 1983). In a recently completed study by B. L. Driver, Glenn E. Haas, and Thomas Greene to test some basic tenets of the Recreation Opportunity Spectrum (ROS) System (Driver and others, in press) new recreation experience preference scales were applied to determine how important "testing the need to rely on one's outdoor skills" and to be "self-reliant in the use of woods skills" were as reasons for hiking, fishing, and camping in Rural to Primitive ROS classes. Those two experience preferences proved to differentiate predictively the visitors to the different settings and were always most highly valued in ROS classes toward the primitive end of the spectrum.

Social Identity Benefits

Contrary to intuition, but consistent with sociological theory, wilderness recreationists aspire to gain many benefits that stem from social interaction. Probably the most pervasive and one of greatest magnitude relates to family cohesiveness and solidarity. Others include strengthening social bonds with small groups of significant others, sharing skills with others, and gaining social recognition or status from demonstration of skills to others and later sharing tales or photographs of enviable experiences. Wilderness use by organizations, including the Outward Bound-type and therapeutic programs, and wilderness tours such as those sponsored by the American Forestry Association can also logically be assumed to provide socially defined benefits to the individuals participating.

Dozens of studies of recreation experience preferences and motivations and of the sociology of wilderness recreationists show that these socially related perceived benefits are quite widespread and of considerable value (Brown 1981; Cheek 1981; Heberlein 1977; Kelly 1981; Lee 1977; Schreyer and Roggenbuck 1978b; Stankey 1972). See also the mean ranks of experience preference domains 6 (share similar values) and 8 (family kinship) in table 2. Lucas (1980) showed behavioral correlates to these types of results in that, with one exception, 51-63 percent of the user groups sampled in the nine wildernesses he studied were either in family groups (which represented by far the larger percentage of any group) or groups made up of family and friends. Also, roughly 40 percent of the parties included children under 16 years old, and less than 6 percent were visiting any of the nine wildernesses alone.

Perhaps more abstract, but still of considerable personal and social significance, are the benefits of leisure (including wilderness recreation) in nurturing various dimensions of social cohesion. Establishment of trust, open communication, and sharing of ideals and problems are enhanced under conditions where formality and role barriers are reduced (Cheek 1981). It is during these times that persons gain and share information about some of their most important decisions.

Educational Benefits

Numerous studies of on-site wilderness users document that exploring and learning about nature—even getting a feel for the geography of a particular piece of land—are important to practically all wilderness recreationists. Those desires ranked second to fourth in importance in all but one (Maroon Bells-Snowmass) wilderness in table 2 (see experience preference domain 5). Confirming results can be found in the dozens of river recreation studies by Lime and his associates and by other researchers (Ditton 1981; Lee and others 1982; Peterson 1971).

It seems reasonable to propose that off-site users realize sizable educational benefits from the time they devote to reading wilderness literature (coffee-table-size illustrated atlases, National Geographic magazines) and to watching TV specials devoted to wildlands and animals, and from knowledge obtained from their memberships in preservation-related organizations. This learning could prompt other benefits, such as greater behavioral commitment to conservation and preservation and support of a prudent approach to resource development. Of course, others with developmental interests could view these values as constraining their realization of benefits defined in a different context.

Spiritual Benefits

People today acknowledge the wisdom of the many people, including the American Indians and other aboriginals, who regarded places, not just buildings with steeples, as sacred. Wilderness appreciation in Europe and America really began with the revolutionary idea that the least-modified environments were the purest expressions of God's power and glory. From the transcendentalism of Henry David Thoreau and Ralph Waldo Emerson to the "cathedral mountains" of John Denver, wilderness acquires importance as a setting for answering the deepest questions of human existence, for celebrating the creative power behind life and things, and for understanding the unity of them all. These are religious functions (Graber 1976), which suggests that the American wilderness could be defended by the Constitutional guarantee of freedom for citizens to worship as they choose. Even if those who look upon wilderness as a church are a minority, protection of a minority's right to worship in its own way is a basic part of the American democratic creed, despite the difficult task of determining the type and size of wildernesses needed to meet these rights.

Some research findings do show that development and expression of spiritual values are important dimensions of the wilderness experience. For example, in table 2, domain 9 (introspection/spiritual) ranks of a little to moderate importance and tends to be valued slightly higher in most of the wilderness areas than the nonwilderness areas. Rossman and Ulehla (1977) too found that their sample of University of Colorado students reported very important "psychological reward values" (potentially available from wildernesses) from having the "chance for spiritually uplifting experiences."

Esthetic/Creativity Benefits

In our concluding section, we will suggest that it might be counterproductive to base a wilderness philosophy on values, such as scenery, that can be realized in substitute areas. We believe the broader concept of esthetics—which perhaps should include spiritual development—is a justifiable base. Nevertheless, we cannot deny that scenic enjoyment in and of itself is an important motivator of wilderness use. Despite this conflict, our rationale is based on the belief that beyond scenery there is a particular kind of beauty dependent on wilderness settings. Beginning in the 17th and 18th centuries, romantics called it the sublime. It stemmed not from near-pastoral environments but from vast, disordered, powerful, awesome places that reflected the frailty of human beings. The idea of sublimity, for instance, transformed human views of mountains from warts and pimples disfiguring the earth to majestic, beautiful features. People began to climb them for pleasure. Painters like Albert Bierstadt and Thomas Moran and photographers like Ansel Adams publicized the new esthetics. The current popularity of wilderness art dramatizes the fact that contemporary artists and appreciators of art still find unique esthetic value and opportunities for creative expression in wilderness settings.

There is considerable documentation of the perceived esthetic value of wilderness. In a word-association study by Heberlein (1982), the word "beauty" ranked fifth (of the 36 reported) in frequency of being free-associated with the word wilderness. One of the first studies of wilderness experience preferences reported that esthetics were rated of the highest importance to the visitors surveyed in the Mount Marcy Wilderness in the Adirondacks (Shafer and Mietz 1969). Table 2 shows that the experience domain "enjoy nature" ranked first in importance across all the designated wildernesses and all but one (Vermont) of the de facto wildernesses. The data are not provided in table 2, but the scale "scenery" (see table 3) received slightly higher mean scores than the other scale constituting the "enjoy nature" domain. Although the scale "creativity" was not included in most of the studies shown in table 2, it was included in studies of the Flattops, Rawah, Linville Gorge, Shining Rock, and Joyce Kilmer/Slickrock Wildernesses and received mean scores indicating moderate importance.

This pattern of values for esthetics and scenery is confirmed by Brown (1981) in his summary matrix of highly valued experiences derived from outdoor recreation, including recreation in wilderness areas. Finally, in response to an open-ended question asking visitors why they chose to visit a roadless wilderness instead of some other type of area, "scenic beauty" ranked (by frequency of being mentioned) as second in five, third in two, and fourth in two of the nine areas studied by Lucas (1980).

Despite the high ratings of esthetic/scenic appreciation in all wilderness studies measuring that preference, Anderson (1981) raises a caution. She found that student subjects at the University of Arizona rated slides labeled "wilderness area" and "natural park" higher than those designated "commercial timber stand," "leased grazing range," "national forest," and "recreation area" despite the fact that six randomly selected subsets of slides of the same area (not of six different areas) were shown to solicit each of the valuations; the slides were all of the same area, and only the labels assigned to the six randomly selected subsets of slides differed. The slides of the area were selected to exclude much modification by humans because of the inclusion of the wilderness area category in the experiment. The caution is that scenic qualities are a part of people's image of wilderness whether or not such qualities are in fact greater in a particular wilderness than elsewhere; just the label "wilderness" elicited those images in the Anderson study.

Symbolic Benefits

This category denotes benefits that people realize just from knowing that wild things are being preserved consistent with their preference. As Wohlwill (1983, p. 86) puts it, "Nature represents a construct, that is a product of our intellect and imagination, defining the characteristics, as well as the power that we attribute to it." Thus, we can and do attribute values to preservation consistent with our values and beliefs, and we must benefit from any consonant perceptions. Again, the context is important; others could perceive loss of benefits if their values favor development.

Specific dimensions of these symbolic values include the benefits individuals derive just from knowing that society collectively is being a good steward through conservation and preservation actions. Included are the existence, option, and bequest demands studied by economists (Walsh and others 1984). Haas and others (1983) found that two groups of Colorado residents, who had and had not visited wildernesses, both believed the fourth and fifth most important reasons (out of 13) for preserving wilderness were "knowing that future generations will have wilderness" and "knowing that in the future you have the option to go there." Also at the personal, as well as the social, level are ethical/moral sentiments (Rolston 1981) about human responsibilities to respect nonhuman organisms (discussed in greater length in the section on Inherent/Intrinsic Benefits).

It is quite difficult to appraise these symbolic benefits. Kellert (1983) reports from his national survey that a moralistic attitude toward animals, especially wildlife, was the second most prevalent attitude toward animals, including wildlife. He defined that attitude as "primary concern for the right and wrong treatment of animals." Another attitude with ethical overtones, ecologistic (concern about the environment as a system), was pervasive but of lower overall rank. More (1977) examined the index of "Children's Books in Print, 1972" to determine the number of titles that included the words "animal" or "wildlife" or mentioned a particular type of animal. Expressing frustration that he had to pass up "Little Red Riding Hood" and "Bambi," he found that in 1972, of the 40,250 children's books in print, 5,473 (13.6 percent) had one or more animals mentioned in the title. He discusses some of the possible effects of this imagery or symbolism, and suggests the impacts are considerable on the attitudes and behavior of the children and their maturation. Some animals commonly associated with wilderness are important for this symbolism. Nash (1982) established that the word "wilderness" has always had symbolic value.

Other Personal Wilderness Recreation-Related Benefits

In general, the most salient benefits suggested by many preference studies of wilderness recreationists have been considered in the categories of personal benefits discussed above. Those studies reveal, however, that other less salient benefit-implying conditions are also strongly desired by most users; practically all of the experience preferences shown in table 2 were reported to add at least a little ($\bar{x}=4.0$) to satisfaction by all visitors studied. For example, that table indicates other benefits not emphasized in the taxonomy offered in table 1. Included are autonomy and independence, pitting one's wits against animals hunted or fished, and being stimulated. Other personal benefits suggested by the nonscientific literature include obtaining from wilderness a better appreciation of one's historic roots and a sense of humility.

In addition, the overall most salient perceived benefits inferred from table 2 mask the fact that there are variances around these mean values; other preferences are most salient for particular subgroups. For example, Haas and others (1980) and Manfredo and others (1983) found that one market segment of wilderness users scored much higher on preferences for risk taking than the other segments. Thus, although common overall patterns in benefit-implying, wilderness-related preferences can be documented, there are also particular preferences for different segments of wilderness visitors.

Commodity-Related Benefits

In addition to the noncommodity-related personal benefits, there are benefits to individuals and to society from the commodities and marketed services (water, for example) provided by wilderness areas. Timber used to build houses is harvested from many undesignated wildernesses, and goods and services ultimately provided from other resources (minerals, forage) provide off-site benefits too. The benefits of most importance in this category are probably those that accrue from protection of watersheds. Haas and others (1983) compared two groups of Colorado residents, one that had and another that had not visited wildernesses; both valued the protection of water resources in wilderness the highest among the 13 wilderness-value items listed.

Nurturance Benefits

This last category of personal benefits is novel to the literature and a little more abstract and speculative. It denotes the benefits realized by altruistic people who nurture options for other people to benefit currently from wildernesses. The benefits are to the nurturers, who feel good about themselves for helping provide the opportunities for others currently. Nurturance benefits differ from the economists' idea of bequest values, a related concept in which the implied altruism is directed toward future users.

Our belief is that, just as good teachers nurture opportunities for their students to have rich learning experiences and just as good parents nurture rich living/growing experiences for their children, citizens of a good society nurture the arts, support fluoridation of public drinking water (even if the supporters wear dentures), promote opportunities for leisure enjoyment, and favor sensitivity to nonhuman organisms and future people. We would have no wilderness preservation system if these types of values did not exist. Although these benefits would be difficult to quantify, in aggregate they are probably significant.

Summary on Personal Benefits

To summarize, many different types of personal benefits are found from wilderness preservation and use. However, it could be hazardous to generalize all of the personal benefits of active users of wilderness to all potential users. As Peterson (1971) suggested, wilderness users might not be a random subset of the population. Kaplan (1974) found that participants in the Outdoor Challenge program she studied scored higher on the pretest of self-esteem than the control group of nonparticipants. Young and Crandall (1984) found a little support ($p=0.3$) that potential users of the BWCA scored higher on self-actualization than the other nonusers who were not classified as potential users. There could be some individual differences that predict realization of particular types of benefits. This does not mean that users do not benefit, only that they might benefit differentially from the same type of use. Evidence for this is available from several wilderness market segmentation studies (Brown and Haas 1980; Haas and others 1980; Manfredo and others 1983). These results serve again to show the diversity of benefits probably obtained by users having different preferences.

Lastly, table 2 provides data on general wilderness experience preferences from which inferences to particular types of benefits can be drawn. Those data show that recreational users of wilderness share many dimensions of their preferences with outdoor recreationists using nonwilderness areas. Those data, in addition, show the most consistent pattern in mean rank scores for users of designated wilderness, followed by users of de facto wilderness. This suggests there might be greater predictability of experience preferences for wilderness users than for users of nonwilderness areas. One might infer that specific types of experiences, and perhaps benefits, might be more wilderness dependent than others, but this hypothesis needs further testing.

SOCIAL BENEFITS

Eight classes of social benefits were listed in the taxonomy of wilderness benefits presented in table 1. Some of the categories, especially the "spinoff benefits," largely defy scientific appraisal because of the problem of establishing research controls that would clearly establish cause-effect relationships that link wilderness preservation and use with benefits, while excluding other possible causes of the benefits. Also, some of the benefits probably occur with a time lag that confounds systematic research, as does the difficulty of establishing control groups. Therefore, although some of the proposed types of social benefits of wilderness might well exist and be nurtured through many channels, little research has been done—or

likely will be done—to document this. For that reason, some of this discussion must be speculative.

Aggregate Personal Benefits

This category comprises those personal benefits that, when aggregated, also contribute to collective social welfare. Any health-related or ecological learning ("space-ship earth") benefits are examples.

Although there is no way of measuring the cumulative personal benefits of wilderness that are realized by all users, this sum probably contributes substantially to the quality of American life considering the diversity of personal benefits considered and the number of on- and off-site users, especially the latter. As just one example, the therapeutic and stress-mediating benefits, when aggregated across all beneficiaries, probably represent a sizable total.

Spinoff Benefits

This class of benefits has been labeled "merit good" and "spinoff" benefits in the public finance and welfare economics literature. The benefits are also called external economies, meaning that meritorious or good things are spun off to nonconsumers (nonusers) from the production or consumption of a particular good or service. Public education has been the classic example; if citizens are educated, they supposedly are more productive people, less prone to antisocial behavior, and can participate more intelligently in a democracy (voting, volunteer work, etc.). Thus, society in general benefits as a side effect of citizens being educated.

One subclass of possible external economies from wilderness preservation and use denotes a type of personal benefit that creates a similar but not identical benefit to society. If people restore adaptive and work energies while using a recreation (Grubb 1975) or wilderness area and as a consequence show increases in the subsequent quality or quantity of their work, those individuals benefit from increased pride in work, more job security, and perhaps advancement in position and salary. The spinoff benefits to society are increased productivity, improved comparative advantage, and increased national economic wealth. The personal and social benefits differ some, but both relate to increased productivity and wealth. The second class of spinoff benefit denotes that a type of social benefit is created different than the benefit realized by the users from whom the spinoff originated. Both on- and off-site users, for example, might obtain increased national pride from knowing that their country thinks as a matter of principle it is important to preserve part of its natural bounty and cultural heritage. This enhanced pride could spin off into greater social cohesiveness or even greater participation in social institutions such as voting in public elections. Or, individuals might support and benefit personally from wilderness preservation solely because they wish to maintain options to use the areas in the future, and that support helps create the opportunity to develop later from a preserved species a drug that promotes human health collectively.

One can reasonably speculate that there are beneficial social spinoffs of wilderness use and preservation that take the form of increased work productivity, reduced public subsidy for mental and physical health, advantageous consequences of any stress mediation-related personal benefits, and better social bondings. The problem is there are diverse factors (physical features of home, neighborhood, and work environments, marital and family status, cognitive style, education, age, personality, other leisure behaviors, patterns of social interactions of the users, etc.) that can separately and interactively (with wilderness use) cause desirable changes in society. There is also the difficulty of defining what these social spinoff benefits are (such as collective improved mental health or a higher overall quality of life). For these reasons, it is impossible to determine how many spinoff benefits there are from wilderness. We will continue to rely on the political-democratic process, rather than scientific inquiry, to register public sentiments about these relatively intangible benefits.

Historical Cultural Benefits

The United States achieved political independence before it attained cultural independence because of provincialism —Americans felt inferior to the Old World. There was little distinctive or distinguished about American culture or character. The most hostile America-baiters even alleged that the new heterogeneous nation in the backwoods lacked a culture—that it was not a bona fide nation at all (Nash 1982). In response, Americans searched for something that was different and impressive about their country. Wilderness came to the rescue. The New World might not have the history and tradition of Europe, but it was abundantly endowed with wilderness. Moreover, since wild environments possessed spiritual and esthetic uniqueness compared to modified ones, it followed that Americans could use them for cultural purposes. This train of thought transformed wilderness from an embarrassing liability to a coveted asset. Americans did not have to be cultural copycats anymore. Europe might have its Roman ruins and medieval cathedrals, its Leonardos and Shakespeares, but America had Niagara Falls, buffalo, Indians, and the Rocky Mountains. Sure the Alps were mountains, but highly developed ones, saturated with civilization. Its vast and undeveloped wildlands and resources gave the new nation the substance for national pride.

In time, of course, American artists and writers realized the promise of the wildness of the New World. James Fenimore Cooper and Thomas Cole led the way in the 1820's, producing the first critically celebrated and distinctively American novels and paintings, and it was their use of wilderness that set them apart (Nash 1982). Subsequent Western painters—one thinks of George Catlin, Charles M. Russell—and contemporary artists carried on the tradition of using nature as a basis of nationalism.

Wilderness has also made substantial contributions to national character. In 1936, Gertrude Stein, long a resident of Europe, put her finger on an important fact. "In America," she wrote, "there are more places where nobody is than where anybody is. That is what makes

America what it is." Stein was referring to wilderness as a shaping force on America and Americans. The frontier, as the historian Frederick Jackson Turner (1920) pointed out, is the quintessential American historical environment, the shared situation that shaped the national character. Writing in 1893 only 3 years after the census pronounced the American frontier dead, Turner implied that wilderness was the best means of sustaining essential American traits like the love of freedom and democracy. He sensed that eliminating wilderness would be comparable to tearing the pages out of a library book.

The love of liberty is one of the hallmarks of American national character, and there has been a deep historical relationship between wilderness and freedom. Wallace Stegner has a beautiful way of expressing it. In 1960, he called wilderness and the idea of wilderness "part of the geography of hope" (Nash 1976, p. 192). It was an environment that permitted people to be different, to experiment, to resist, to rebel. The Puritans, fleeing the repressive culture of a nation that did not permit them religious freedom, began the tradition in the 17th century. The Mormons continued it in the 19th century when they migrated to the wilderness of Utah. Edward Abbey (1968, p. 149) still sees "political reasons" for preserving wilderness, as refuges from authoritarian and totalitarian systems of government. Freedom fighters traditionally take to the wilds—as long as there are wilds available. It was no accident that in his book "1984" George Orwell (1949) made one of Big Brother's first acts the elimination of wilderness.

The notion of freedom as a benefit of wilderness is supported too by table 2, which shows that "independence" (domain 7) was rated of moderate and slightly higher importance in the 12 wildernesses studied.

Preservation-Related Benefits

It is almost tautological to say that one of the consequences of wilderness management is to preserve wilderness resources. The difficult question is, What are the benefits from such preservations? Again, several subcategories of benefits appear to exist.

Representative Ecosystems.—A major reason for preserving wilderness is to protect and maintain representative ecosystems in different regions of the country. At face value, such efforts seem meritorious because almost all the ecology texts and articles reviewed proceeded under the assumption that preservation of representative ecosystems in their natural states is a good thing. Although articles have described wilderness ecosystems (Franklin 1978), provided general information about the benefits of ecosystem preservation (Westman 1977), or offered criteria for selecting areas, few have offered much help directly in appraising what the benefits are. One exception was the selection criteria offered by Margules and Usher (1984), which included several (amenity value, educational value, and scientific value) from which inferences to benefits could be made. Lucas (1984) was one of the few authors to discuss explicitly the benefits of conserved and preserved areas in the proceedings of the Bali World Congress on National Parks, even though the title of those proceedings was "The Role of Protected Areas in Sustaining Society."

Some authors have argued that ecosystem preservation is desirable because such actions will lead to increased stability and greater species diversity. Others suggest that, while diversity and stability are not always correlated, "they have had evolutionary relationships that run parallel [and that]. . .high environmental stability leads to high community stability, which, in turn permits, though is not determined by, high diversity of species" (Myers 1979, p. 49). Dasmann (1978) is more specific and points out failures of past authors to define terms adequately. He defines stability in terms of constancy and persistence, not absence of change. He then considers relationships between these two characteristics and resiliency and species diversity to point out the complexity of these interactions by his statement, "There is no clear relationship between diversity and stability or diversity and resilience" (p. 20). His message, which we find useful, is that "instead of one simple relationship there are many. . .to be investigated" (p. 20) from the relatively unstable and less resilient tropical rain forests to the *Spartina* marshes that are highly stable and resilient.

The inability to generalize from ecosystem to ecosystem and statements that things are complex and the consequences of disturbances unknown are frustrating to the nonecologist interested in beneficial functions. Still, this uncertainty and the potential for irreversibility are reasons for preserving representative ecosystems at least until more knowledge is obtained. Bishop (1978) has suggested that the economic costs of such preservation will be modest.

The foremost benefits of preserving representative ecosystems appear to be those of acting prudently in the face of uncertainty, which comes down to risk aversion—of preventing unknown and unwanted costs from being disclosed in the future. These are equivalent to the benefits realized by individuals who prudently undertake health-maintenance activities under a probabilistic stance; they feel better about it and might benefit in the future.

Species Diversity.—More definitive arguments have been made in the literature about the benefits of maintaining species diversity than about ecosystem preservation, even though the two are largely inseparable. But again many authors write as if the reader already understands why the preservation of species diversity (or of germ plasm) is good. Sparrowe and Wight (1975) offer a highly detailed list of biological characteristics and weights for use in setting priorities for the endangered species program. Although it was not their purpose to discuss benefits, no criteria were (and probably could not be) offered regarding the probable benefits of preserving the different species to which the system was applied. Similarly, Stone (1965) reported that we do not have clear objectives for preserving vegetation in parks and wilderness. Walsh (1981) reports that "germ plasm resources are losing ground," but he does not discuss why that is a problem.

Like preservation of representative ecosystems, some benefits of species preservation can be attributed directly to such preservation action while other benefits might or might not be directly related. We will consider here those that are directly related.

Several surveys studying the meanings and values of wildlife—although not necessarily wilderness-dependent

wildlife—give some feel for the perceived benefits of species preservation. Kellert (1980), in a national sample (3,107 respondents), developed and applied a 10-dimensional typology of attitudes toward wildlife. He has reported on these and other measures made in several publications. The attitudes and Kellert's (1980, p. 34-35) definition of each are shown in table 4, along with his (p. 37) estimate of the percentages of the sample population strongly oriented toward each attitude and the common behavioral expressions and benefits related to each. The table indicates several perceived benefits related to maintaining diversity, especially attitudes 2, 4, 5, and 7.

Shaw's (1979) study of antihunting sentiments solicited ratings from three groups of Michigan respondents of reasons why wildlife were important to them. The groups were Michigan deer hunters, Audubon Society members, and supporters for the Fund for Animals. The respondents rated these reasons from most to least important: (1) wildlife is a part of the ecological balance upon which we are all dependent; (2) people enjoy viewing wildlife; (3) people enjoy just knowing that wildlife exists; (4) wildlife is of scientific value; (5) wildlife plays an important part in our cultural heritage (songs, legend, etc.); (6) wildlife provides hunting recreation; (7) wildlife helps the economy by attracting tourism; (8) wildlife are a source of food and furs; (9) and wildlife have souls like humans. Again, benefits are either explicitly stated or implied by many of these reasons. One can infer that maintenance of species diversity would be viewed as fundamental to the highest rated sentiment, maintaining ecological balance.

Interestingly, the three diverse and frequently conflicting groups studied differed little in the mean importance

Table 4.—Kellert's (1980) typology of attitudes toward wildlife and inferences to possible benefits

Attitude typology	Estimated percentage of American population strongly oriented toward the attitude[1]	Common behavioral expressions	Most related values/benefits
1. **Naturalistic:** Primary interest and affection for wildlife and the outdoors.	10	Outdoor wildlife-related recreation—backcountry use, nature birding, and nature hunting	Outdoor recreation
2. **Ecologistic:** Primary concern for the environment as a system, for interrelationships between wildlife species and natural habitats.	7	Conservation support, activism and membership, ecological study	Ecological
3. **Humanistic:** Primary interest in and strong affection for individual animals, principally pets. Regarding wildlife, focus is on large attractive animals with strong anthropomorphic association.	35	Pets, wildlife tourism, casual zoo visitation	Companionship, affection
4. **Moralistic:** Primary concern for the right and wrong treatment of animals, with strong opposition to exploitation or cruelty toward animals.	20	Animal welfare support/membership, kindness to animals	Ethical existence
5. **Scientistic:** Primary interest in the physical attributes and biological functioning of animals.	1	Scientific study/hobbies, collecting	Scientific
6. **Esthetic:** Primary interest in the artistic and symbolic characteristics of animals.	15	Nature appreciation, art, wildlife tourism	Esthetic
7. **Utilitarian:** Primary concern for the practical and material value of animals.	20	Consumption of furs, raising meat, bounties, meat hunting	Consumptive, utilitarian
8. **Dominionistic:** Primary satisfactions derived from mastery and control over animals, typically in sporting situations.	3	Animal spectator sports, trophy hunting	Sporting
9. **Negativistic:** Primary orientation an active avoidance of animals due to fear or dislike.	2	Cruelty, overt fear behavior	Little or negative
10. **Neutralistic:** Primary orientation a passive avoidance of animals due to indifference.	35	Avoidance of animal behavior	Little or negative

[1]Totals sum to more than 100 percent because some people were strongly oriented toward more than one attitude.

scores they gave to the five top-ranked reasons. Similarly, Haas (1980) found that those Colorado residents who had, and those who had not, visited wildernesses both ranked 13 reasons for protecting wilderness almost identically. Those reasons included maintenance of species diversity.

Arthur (1979) too, in a national survey (of 2,460 respondents), asked the subjects to rate the importance of several aspects of wildlife on a 0-10 scale where 0 represented "no importance" and 10 "extreme importance." The ratings (and mean values) were: ecological value (8.9), existence value (8.6), viewing pleasure (8.3), food source (4.8), hunting opportunity (3.8), and fur source (2.5). The high ratings given to "ecological" and "existence" values suggest personal and social benefits related to maintaining species diversity.

Hendee and Schoenfeld (1978) proposed three categories of wilderness wildlife: wilderness-dependent, wilderness-associated, and wildlife not dependent or associated. Although no differentiation was made between wilderness-dependent and other wildlife in the Kellert, Shaw, and Arthur studies, it seems reasonable to propose that preservation of species of wildlife that are wilderness-dependent were valued as strongly and for similar reasons as non-wilderness wildlife were in those three studies.

Regarding a wilderness-dependent species, the grizzly bear, Kellert (1979) found in his national survey that 56 percent of the respondents agreed with the statement, "It has been suggested that 5 million acres of National Forest land be set aside so that the endangered grizzly bear remain undisturbed. The timber industry objects, saying that jobs and needed lumber will be lost. Would you agree to protect the endangered grizzly bear even if it resulted in the loss of some jobs and building material?" It is not known how the wording of the question influenced the responses, for example, how "the loss of **some** jobs and building materials [emphasis added]" was interpreted by the respondents. Results showed 9 percent agreed strongly, 26 percent agreed, 21 percent agreed slightly, and 5 percent were neutral. Directly related to wilderness also was another question in the same study that solicited agreement (44 percent) and disagreement (51 percent) with the statement, "Natural resources must be developed even if the loss of wilderness results in much smaller wildlife populations."

Although these public surveys help point out probable benefits of species diversity, the most convincing arguments for species preservation come from data on the numbers of species that exist, what is not known about most of them, the rate at which they are disappearing, and more importantly the contributions that species of animals and plants have made to medical, agricultural, and industrial progress in the past. Myers (1979) has offered an excellent discussion of these considerations.

According to Myers (1979), the number of species of plants and animals on earth in 1960 was estimated to be about 3 million, and currently there are about 5 to 10 million, with 2 to 6+ million estimated to be in the tropics. He points out, though, that in 1978 only about 1.6 million species had been classified. This means that from one-sixth to one-third of the species thought to exist today have not been identified, so nothing is known about their potential benefits to humans.

Myers also points out that species extinction has been occurring for millions of years; mass extinction about 70 million years ago wiped out about one-quarter of all families, including the dinosaurs and their kin, and some 5 million years ago there may have been one-third more bird species than today. His conclusion is that although the pace of speciation has speeded up "the evolutionary record does not show a steady upward climb in earth's total species, rather a series of step-wise increases" (p. 28).

Myers then suggests that humans caused few species to vanish until at least A.D. 1600. He estimated that by 1900 humans were driving one species extinct every 4 years, and thereafter the rate increased to about one per year; these figures refer to mammal and bird species humans knew existed. He estimates that by the year 2000, one million species will vanish. This is supported by a Smithsonian Institution study (Jenkins and Ayensu 1979) that indicates 10 percent of the plant species in the United States are in jeopardy.

To give temporal dimensions to this increased rate of extinction, Myers (pp. 29 and 30) asks the reader to

> . . . suppose the whole existence of the planet earth is compressed into a single year. Conditions suitable to life do not develop for certain until May, and plants and animals do not become abundant (mostly in the seas) until the end of October. In mid-December, dinosaurs and other reptiles dominate the scene. Mammals, with hairy covering and suckling their young, appear in large numbers only a little before Christmas. On New Year's Eve, at about five minutes to midnight, man emerges. Of these few moments of man's existence, recorded history represents about the time the clock takes to strike twelve. The period since 1600 A.D., when man-induced extinctions have rapidly increased, amounts to 3 seconds, and the quarter-century just begun [1975-2000], when the fallout of species looks likely to be far greater than all mass extinctions of the past put together, takes one-eighth of a second—a twinkling of an eye in evolutionary times.

Although this quote makes one pause and reflect about the role of humans in the grand scheme of things, and perhaps think about our moral and ethical ecological obligations, it does not address the question: What difference does it make if we lose species diversity or specific species?

Myers addresses this question by first considering esthetic and ethical arguments for species preservation while suggesting that humans might desire to see some organisms disappear, like those that cause the common cold and contribute to cancer. He, as have others (Salwasser 1983), also points out that particular species can serve as indicators of environmental change with the most sensitive, including humans, being near the end of the food chains, so they can flash "a red light concerning new threats to our welfare." Characteristically, Myers raises a caveat (p. 51): "But if indicator species can offer us answers to questions we scarcely know how to ask, how are we to pick out the species that serve this valuable function?" The implication is we should be prudent in leading any species to extinction. The conclusion of Brown

and Goldstein (1984) supports that suggestion. Because of much uncertainty, they were unable to show how economic valuations can help in deciding which species to save.

Myers' central argument for preservation of species diversity is quite utilitarian. It is based on the benefits provided to humans by previously "unbeneficial" plants and animals, especially health-related benefits, benefits to increased agricultural stability and productivity, and to industrial processes. He states (p. 60) that "it is the skills of plant geneticists, rather than large amounts of artificial additives, such as pesticides and fertilizers, that have led to one record after another in crop yields in North America and other regions of both temperate and tropical zones." He gives many examples of how new species and varieties have either contributed to agricultural productivity or have the potential to do so, for example:

1. Sorghum productivity took a big leap forward following analyses of 9,000 forms of sorghum that produced two types rich in lysine (an amino acid).
2. A strain of barley has been developed that can grow in sand dunes and be irrigated with sea water.
3. Forms of commercial wheat evolved from primitive wheats found in Asia Minor, where disease-resistant varieties have also evolved.
4. More than 250 cases of partial or complete control of insect pests and weed problems have been documented through the introduction into North America of predator or parasite species.
5. Introductions into the United States of a wild strain of wheat resistant to common and dwarf "bunts" and several other diseases and of a fresh strain of onions resistant to thrips disease have together been estimated to be worth $53.5 million annually in increased productivity (farm gate value).

Examples mentioned by Myers of benefits to medical science include:

1. As many as one-half of all prescriptions written in the United States each year contain a drug of natural origin. These include anticoagulants, antibiotics, heart drugs, antileukemic agents, enzymes, and hormones.
2. Studies of animals also offer medical clues to the origins and nature of disease and to preventative mechanisms. Elephants have helped increase understanding of atherosclerosis and problems of fatty acids. Primates are especially valuable to medical research because of their relatedness to humans. Furthermore, the armadillo is the only animal other than humans known to get leprosy.

These medicinal values are reported by the many researchers referenced by Myers and by others such as Dasmann (1978), who states:

> The precise value of species that are still little known is impossible to predict, but it is well to remember that medical science now makes use of species once considered worthless—that might easily have been allowed to become extinct on the grounds that they were "good for nothing." The present use of *Penicillium* mold (antibiotics), Rhesus monkeys (blood groups), sea urchins (embryology), cinchona bushes (quinine), *Xenopus* toads (pregnancy tests), *Strychnos* vines (curare), foxgloves (digitalis), and *Rauwolfia* (hypertension) could not have been predicted (except perhaps by practitioners of folk medicine, who were familiar with the curative properties of many of these species). Similar contributions are made by wild species to agricultural production, to pest control, and to the development of new domestic varieties. Each species is a storehouse of irreplaceable genetic material whose loss we cannot afford.

Continuing in a very utilitarian vein, Myers also gives examples of industrial products made from wild species: latex products (rubber), pectins, resins, gums and other exudates, essential oils for flavors and related juices, vegetable dyes and tannins, vegetable fats, insecticides, growth regulators, plant-based lubricants, and fuel.

Despite new discoveries each year of the agricultural, medical, and industrial benefits of wild plants and animals, most species have not yet been studied. If such species are not preserved, any latent benefits will be irrevocably lost. The probability of new beneficial discoveries increases as the state-of-the-art of genetic engineering (gene splitting, etc.) continues to advance rapidly (Weaver 1984).

Again, we do not mean to imply that all of the benefits of species diversity discussed can be attributed to wilderness preservation, especially since only a small percentage of Earth's species are found in wilderness in the United States, the focus of this paper. We attempt only to make the point that we do not know what future benefits, especially of a utilitarian nature, might be created by new discoveries. For this reason alone it seems prudent to preserve species diversity. The argument could be made that if there were no other benefits of wilderness preservation in the United States, such preservation could be justified solely on the grounds that we need to demonstrate good faith to other countries on whom we are primarily dependent for novel sources of germ plasm. We have no idea of how large such a U.S. system of demonstration wilderness should be, but it should include representative ecosystems to serve this purpose meaningfully.

Air Visibility.—The 1977 amendments to the 1970 Clean Air Act implicitly recognized the benefits of maintaining clean air and protecting scenic vistas by requiring that standards for air visibility be established over "nationally significant natural areas." These Class I areas include primarily our wilderness areas and National Parks. Although no direct research has been done to specify and quantify these benefits, Driver and others (1979) proposed that these benefits relate to maintenance of conditions necessary for the realization of other benefits sought in the protected areas, namely being able to see out from vistas (esthetics), to orienteer (self-sufficiency), and to protect the wilderness gestalt on which spiritual and other benefits (stewardship) depend.

Ross and others (1983) found that when air visibility (standard visual range) was reduced at the Grand Canyon National Park the visitors noticed it, and many told the National Park Service interpreters that their enjoyment was compromised. They reported too that of 24 park attributes listed, clean, clear air was the third most important attribute (following cleanliness of the park and deep gorges), with 82 percent of the respondents saying it was very to extremely important. The summary of another

report (Ross and Malm 1983) that included results of a study of Mesa Verde National Park states, "Results... showed that the majority of respondents at both parks indicated they were aware of haze and that awareness detracted from their overall park enjoyment." Thus, if maintenance of air visibility is not a benefit itself, it is a facilitator of other benefits.

Economists have made several studies attempting to determine the monetary worth of air visibility (Rowe and Chestnut 1983; Schultze and others 1983). Those economic valuations are part of the Economic Benefits section considered later, but we mention them here as support for air visibility benefits, because so little research has been done on that topic.

Unique Landforms, Historic Sites, Educational Values, and Options for Research.—The Wilderness Act defines wilderness along four dimensions, with the fourth stating wilderness areas "may also contain ecological, geological, or other features of scientific, educational, scenic or historical value." Some of these benefits of wilderness were listed separately in our taxonomy, because of their individual importance. They are combined here because little systematic research has been done on them beyond that discussed under the section on Personal Benefits.

Unique landforms are preserved in many wilderness areas, especially in the National Park System, and many of these areas (Yellowstone, Grand Canyon, and Yosemite) are valued internationally for their unique geological features and their scenic values. As documented under the section on Esthetic/Creativity Personal Benefits, evidence abounds that preferences for unique landforms, including scenic resources, in wilderness areas are strong, and use of such areas is high. On-site users spend literally millions of dollars each year on obtaining photographs of such areas, and scenic quality is frequently the most important characteristic of popular tourist destinations. Furthermore, oil, watercolor, and acrylic paintings of these resources are extremely popular as are articles and entire coffee-table volumes featuring them. Also, scenic wildland backdrops are used in advertisements for many products.

Despite these evidences of social value, we found no systematic research to describe the collective or social benefits of preserved unique landforms. Nevertheless, we retained this category of benefit because its generic qualities permit strong inference of considerable social benefits of a synergistic nature. This concept was expressed in the Outdoor Recreation Resources Review Commission (1962) report on wilderness several years before the Wilderness Act was passed: "It seems manifestly true that the real worth of any exceptional thing lies not alone in its entity but as well in the influence it casts over an array of things." Specifically, novelty of geological formation, vastness of scale, and scenic beauty interact with other features of wilderness to create a whole that is greater than the sum of the parts. Part of nurturance, existence, and bequest benefits related to wilderness are associated with desires to preserve and pass on to future generations this uniqueness and beauty. However, these dimensions are difficult to parcel out discretely from other aspects, such as maintenance of species diversity, simply because a wilderness is a system that functions as a whole because of the interdependency of its parts. Similarly, the concept and benefits of wilderness as a cathedral, or sacred place (Graber 1976), are frequently associated with sites at which spectacular features, including outstanding scenery, are part of a gestalt that loses some meaning with dissection or scientific reduction. Although some dimensions of personal benefit can be analyzed and assumptions made about aggregate contributions to social welfare and increases in the quality of American life, essentially one is left primarily with strong inferences about social benefits based on pervasive indicators.

Although most of the educational benefits of wilderness are of a personal nature, there are most certainly social benefits, too. Probably the most significant is better collective appreciation by a society of its dependency on ecological processes for basic life-support systems. Such understanding from any source can help deter environmental modifications that adversely impact human welfare. Less related to survival and more qualitative in nature are the learning benefits that contribute to any collective environmental ethics that are shared and valued by many in a society.

The major scientific benefits of wilderness preservation are probably those that can (and will in the future) be attributed to maintenance of species diversity. Because many wilderness areas have not been modified greatly by human activity, they also offer unique opportunities for scientific studies of natural processes in relatively undisturbed areas. As the ORRRC (1962) wilderness report points out, many concepts of ecology

> ...are founded on conditions resulting from natural processes.... Such conditions are more closely maintained in areas where primarily indigenous species are represented and where the ecology is "system-dependent." That is, the interactions among species and between them and their environment depend on processes generated by the system itself. Such system interactions are not possible in most of the small "natural areas" set aside throughout the country, but they are approximated in extensive wilderness areas.

This statement was made before passage of the Wilderness Act and was addressed to acreages much larger than 5,000 acres, so it applies to many but not all designated and undesignated wilderness.

In addition to being relatively undisturbed natural laboratories for research on the history, structure, and functioning of whole ecosystems, wildernesses also provide settings for the study of characteristics of individual species and their environmental requirements. They serve also as indicators of environmental trends, whether in reduced air visibility or increases in the adverse impacts of acid rain on plant and animal species and communities. They provide control, or comparison, areas in hydrologic studies of effects of vegetative manipulation on water flows and of the characteristics and dynamics of wildfires and of infestations of insects and diseases.

Stewardship Benefits.—Social stewardship benefits comprise a subcategory of preservation-related benefits that accrue both to individuals and to a society from knowing actions are being taken to preserve options for current and future generations to enjoy and use wilder-

ness resources; to respect the "rights" of nonhuman organisms to live; and even to grant that these organisms themselves benefit from preservation efforts. Although largely symbolic (see discussion under Personal Benefits), these benefits go beyond concerns for future generations and include the notion that humans have responsibilities to recognize and appreciate their place in nature and to temper the notion of human supremacy and "power to have dominion" in the short run.

Many people believe that a society is wrong-headed—with confused values and an unrealistic perspective about its long-term destiny—if it doesn't preserve some areas. Evidences of stewardship benefits can be interpreted from the reasons reported for preserving wildlife (under Species Diversity Benefits) in the Kellert, Shaw, and Arthur studies. These stewardship benefits have been pervasively espoused in the past (Marsh 1864; Muir 1916; Marshall 1930) and still are in the current literature (especially the Journal of Environmental Ethics). Perhaps the most articulate and influential spokesperson for these ideals was Leopold (1949), with his call for a land ethic. These beliefs are reflected in part by the diverse and significant environmental legislation passed in the 1960's and 1970's. These wise stewardship values have apparently increased in significance: new organizations espousing these values (Friends of the Earth, Fund for Wildlife) have emerged; these values are reflected in the Secretary of Interior's 1986 campaign to "Take Pride in America," and they are projected to constitute a primary recommendation of the President's Commission on Americans Outdoors (Jordan 1986).

Quality of Life Benefits

Another category of probable social benefits that has been addressed in the early literature, but infrequently in recent studies focusing on wilderness (McCloskey and Gilligan 1969), is what has been called improvements in the overall quality of life. This, a rather abstract concept, has emerged from research on factors perceived to contribute to overall life satisfaction of the respondents. Those studies (Campbell 1982) show the top five contributors to life satisfaction are economic security, marital/family relationships, health conditions, self-concept, and environmental amenities. It seems reasonable to conjecture, until more wilderness-specific research is done, that wilderness preservation is a contributing factor to the environmental amenities component of a quality life for many on- and off-site users.

Commodity-Related Benefits

In addition to preservation-related benefits, society reaps many advantages from the goods produced from wilderness areas. Designated wilderness areas protect the headwaters of many regionally and nationally important rivers, and impoundments are found in some areas. Although constrained by the Wilderness Act, mineral and grazing-related commodities are also produced on these areas as are opportunities for commercial recreation. These and other commodities, including timber products, are produced from nondesignated wilderness resources, and these commodities are used because of the benefits they produce.

The argument is sometimes made that designated wildernesses cause inappropriate and unnecessary costs to society because they lock up resources with commodity values, especially minerals and timber. Because our purposes are to look at the benefits, rather than the costs and the net benefits of wilderness, we will not address that argument. We will suggest, though, that several studies have indicated that the timber-related opportunity costs (for example, forgone benefits) of wilderness are relatively small for a moderate-sized wilderness preservation system (Teeguarden 1981) or can be offset by more effective management of nonwilderness lands (Hyde 1983). If these costs should become socially excessive, the American people through Congress can in the future change provisions of the Wilderness Act.

Economic Benefits

Benefits to National Economic Development.—Benefits were defined in this paper as improvements in conditions of individuals or society or the prevention of deterioration in desired conditions. We have focused on the improved conditions rather than the economic worth of the wilderness-related goods and services that provide these benefits, which has been the concern of economists studying how wilderness use (including off-site use) contributes to national economic development or welfare. These contributions to national economic welfare are indexed by consumers' willingness to pay for the wilderness-related goods and services. This economic information is useful in ascertaining whether economically efficient allocations of public resources are being made in the short run, with such efficiency being a desirable state—or beneficial condition. To the extent these economic efficiency analyses do not include the economic worth of all benefits, the estimated worth of benefits reported is inaccurate and the future is discounted inappropriately.

Besides helping prevent wasteful resource allocations, the economic efficiency measures also help index the magnitude of wilderness-related benefits in units commensurate with those used to estimate the worth of other goods and services produced from public lands. Such indexing provides information to the resource allocation process in a form that usefully supplements other information inputs (Randall 1984); for wilderness benefits this has generally been highly subjective or intuitive. The economic studies also are useful in identifying specific characteristics or attributes of wilderness that are most valued.

Although many studies have been made of the economic values of public amenity resources using variations (travel costs, contingent valuation, hedonic methods) of the willingness-to-pay approach (Dwyer and others 1977), a relatively small subset have focused on wilderness. Sorg and Loomis (1984) reviewed and made methodological adjustments to willingness-to-pay data from several economic studies of wilderness recreationists, primarily hikers and backpacking campers. Most of the values (in 1982 inflation-adjusted values using the GNP price index) ranged from $13 to $20 per activity day (a variable portion of each day devoted to the primary trip activity).

Those studies included two by Walsh and his associates. In one, Walsh and others (1984) reported similar values for hiking and cross-country skiing in nonroaded areas on the Roosevelt National Forest in Colorado. Other economic studies of on-site wilderness users have also been made. One study reported visitors to a scenic overview in Bryce Canyon National Park (Utah) were willing to pay $62 to $71 per vehicle (Johnson and Haspel 1983).

Economic studies of preservation efforts have also been made of the existence, bequest, and option values of wilderness resources as expressed by both on- and off-site users (Bishop 1982; McConnell 1983; Randall and Stoll 1983). One of the first, a study of the economic benefits of preserving Hells Canyon of the Snake River by Krutilla (1970), established the significance such data can play in policy formation and public resource allocations. The Krutilla study helped show that the benefits of preserving the Canyon compared favorably with development for other uses. The many subsequent studies include the report by Schultze and eight others (1983) on their household survey of willingness to pay to preserve visibility in Grand Canyon, Mesa Verde, and Zion National Parks; the Walsh and others (1984) household survey in Colorado of the option, existence, and bequest demands for Colorado wilderness; and the Walsh and others (1985) study of Colorado user and nonuser households' willingness to pay for preservation of wild and scenic rivers in Colorado.

Other economic studies of on- and off-site wilderness users provided increased knowledge about specific components of wilderness that are most highly valued. An example is the Walsh and Gilliam (1982) study of the effect of congestion on willingness to pay by users in the Indian Peaks Wilderness in Colorado.

Practically all of the wilderness-related economic studies reviewed reported relatively large willingness-to-pay values for the preservation efforts studied. Whether or not the techniques used provide dollar indices of benefits with desired accuracy and validity is a moot point at this time, as these recently developed techniques are being refined. Nor do we assume that the techniques index the monetary worth of all benefits such as those unknown to the respondent, the synergistic contribution of one type of wilderness benefit to the holistic bundle of benefits realized by an individual, and especially any spinoff benefits to society collectively not appraised by the individual consumer when estimating his or her willingness to pay for a specified preservation action. Despite these problems, the results indicate sizable economic values, which we believe are related to benefits the respondents perceive they obtain.

Benefits to Regional and Local Economic Development.—In addition to the just-described contributions that wilderness-related goods and services make to national economic development, wilderness resources, especially superlative and unique features, serve as significant tourist attractions in many localities. They, thereby, contribute to local and regional economic development through their positive impact on area income and employment.

Most States report that tourism/recreation is a leading industrial sector, generally in the top five, and in many States in the top three, in terms of income and employment generated. Although much of these leisure and leisure-related industries are resource-based, it is difficult to parcel out the contribution of wilderness for many reasons. The most troublesome is that tourist/leisure-related industries do not have separate codes in the U.S. Office of Management and Budget's industrial classification system (OMB 1972). Because employment and income generated by these industries is attributed to the other classified sectors within which the tourism-related industries are subsumed, it is difficult to track the economic contributions of these industries. Another accounting difficulty stems from the fact that economically viable tourism complexes offer a variety of activities, interests, and services that interact to form a critical mass (Horvath 1970). The problem with respect to apportioning benefits to wilderness and other attractions is that of knowing relative contributions of each component to the whole, just as it is almost impossible to attribute the contribution of a particular group of musical instruments to the overall quality of a successful symphony orchestra. Lastly, there still is a Protestant ethic bias that discounts the contributions of "play-related" industries to economic growth.

Despite these problems, leisure industries are big business in the United States and most other countries. The proportion represented by wilderness-dependent and wilderness-associated tourism has not been determined. But with the rapid growth in outdoor recreation visitation and expenditures since World War II, especially in dispersed recreation, the contribution of wilderness resources to regional and local economic development is certainly appreciable. However, the other side of the coin is that tourist developments can conflict with the realization of wilderness benefits. The contextual question arises again about whose values define the benefits.

INHERENT/INTRINSIC BENEFITS

This last and least anthropocentric category of benefits of wilderness derives from the notion that nonhuman organisms benefit from wilderness protection—and even that components of the wild ecosystem have interests, perhaps even rights, that humans should respect (Callicott 1985; Leopold 1949; Stone 1974). The roots of this concept in the United States lie in the thoughts of Henry David Thoreau and John Muir (Nash 1982). Albert Schweitzer's "reverence for life" axiom is relevant here, as is Aldo Leopold's "land ethic" and Alfred North Whitehead's "process philosophy." More recently, the Gaia hypothesis—the idea that the Earth as a whole is an organism to which humans belong—gives unprecedented reasons for respecting wilderness (Lovelock 1979). Also germane is the perspective of the "deep ecologists," whose biotic equalitarianism challenges the fundamental premises of anthropocentrism. However, many professional philosophers, such as Lehmann (1981), raise serious objections to these concepts.

On a popular level what the intrinsic value of wilderness signifies is the need for human restraint. Wilderness, in fact, may be the best place to learn that we are members, not masters, of the life community sharing a common habitat and that achievements have been made in the evolutionary process that have resulted in other stories beyond the human story. Permitting wilderness to exist

becomes a gesture of planetary modesty, an expression of humility and gratitude in the face of realities that transcend the short and probably ephemeral human endeavor—the need to recognize some values beyond our human range and scope, such as admiration for overwhelming powers (thunder, waves, sunsets) and skills more developed than our own, such as speed, smell, and endurance (Rolston 1986). A wilderness testifies to the ability of technological civilization to control its capacity for total modification of the Earth. This may be a most meaningful benefit of a preservation policy.

Summary on Knowledge About Benefits

Although we were not always able to reference scientific studies to document the benefits of wilderness considered within our taxonomy, enough research exists to support the firm conclusion that wilderness-related benefits are extremely broad in scope. Because of limitations of the state of knowledge, no firm research-based conclusion can be made about the magnitude of some of these benefits. For some, such as the benefits of preserving species diversity, past contributions to medical, agricultural, and industrial productivity attest to the prudence of avoiding species extinction. For others, such as the therapeutic benefits of wilderness, tremendous untapped opportunities for benefits likely exist. Furthermore, users' willingness to pay for wilderness preservation and for on-site recreational use of wilderness attest to sizable benefits, as do several national surveys showing strong support for wilderness preservation.

Certainly more research is needed to document further the presence or absence of benefits within each class of our taxonomy. Our priorities for that research are reflected in the section that follows. That section also gives our interpretations of categories of benefits that are most relevant to wilderness preservation and to promotion of a wilderness philosophy.

WILDERNESS DEPENDENCY OF BENEFITS

This final section interprets our judgments about which categories of benefits are the most wilderness-dependent and therefore most useful in promoting a sound wilderness philosophy.

From our taxonomy of benefits, we will select and consider briefly those we judge to be the least and the most wilderness dependent. This does not mean that the less dependent values cannot be attributed to wilderness; they can if provided by wilderness. Nevertheless, the most dependent values are those that will best support the promotion of a wilderness philosophy. In the past, the wilderness movement has not always led from it strengths. We must do a better job of articulating the most central wilderness values, especially now as attention focuses on development of agency guidelines and standards for wilderness management and as pressures for alternative uses continue to increase.

Less Central Values

We believe the following benefits attainable from wilderness are less central to promoting a wilderness philosophy: (1) some, but not all, benefits related to skill and self-concept development, therapy, physical health, and social identity; (2) most of the scenic landscape dimensions of the esthetic benefits; (3) those general recreation and nurturance benefits attainable in alternative areas; (4) air visibility benefits; (5) most of the commodity-related benefits; and (6) perhaps even some of the bequest-related benefits.

Except for some of the challenge-type programs and opportunities provided for a particular mode of self-sufficiency, other of the self-concept benefits are not very wilderness dependent. Nor are most outdoor recreation opportunities that contribute to stress mediation, physical fitness, and social interaction. A problem with viewing wildernesses primarily as public outdoor recreation areas is that policy can lead to overuse and diminish opportunities to realize other, what we consider higher, wilderness values.

Although preservation of areas of outstanding scenic beauty is mentioned in the Wilderness Act, we believe that value might be stressed too much. Scenic beauty is not an essential component of wilderness; the absence of civilization is. Now some do find the absence of civilization beautiful, but many others who like wilderness find it weird, strange, mysterious, frightening, harsh, and decidedly unlovely. Edward Abbey, for instance, seldom mentions scenic beauty in his paean to the desert canyonlands of the Southwest. John Muir and the Sierra Club lost the 1913 controversy over Yosemite's Hetch Hetchy Valley because they phrased its defense largely in terms of scenery (Nash 1982). This allowed San Francisco to reply that the dam and reservoir it wanted to build on the Tuolumne River would improve the scenery—reflect it double in fact. Muir would have been better advised to rest his case on the wildness of the valley. The point is that "providing scenic beauty" is not as central as those values that depend specifically on the wildness of an environment. The tendency to think of wilderness as beautiful also complicates the task of managers trying, for instance, to convince the public that fire has a natural place in a wilderness ecosystem.

Arguments about the water and air-visibility benefits of wilderness also do not seem central to promotion of a wilderness philosophy. Good water and air are not dependent on wilderness as are the existence of wolves and grizzlies. Excellent water can come from the vast concrete catchments proposed for parts of the Arizona desert. Water and air are useful arguments, and ones that the public and the politicians readily understand and support. However, if we lean too heavily on them in the defense of wilderness, we run the risk of having that leaning post cut off.

Another possible flaw in the way we commonly defend wilderness is to argue that future generations would mourn its disappearance. But how do we know this? Perhaps appreciation of wilderness will atrophy as it apparently has, for example, among many Europeans and

Chinese. Perhaps people of the future will really prefer to get their wilderness experience from cassette tapes of wind in the pines and videotapes of campfires played on the living room television. It might be better to base the defense of wilderness on historical experience rather than on a hypothetical future valuation. Let's protect and manage wilderness because it is important to us, now. It is good stewardship to pass along options for choices—prevent irreversibilities—but we should exercise care in assuming what those future generations will in fact value and choose.

Finally, although we recognize and support the need—even requirement—of Federal agencies to determine the economic efficiencies of different resource allocations, we do not believe that promotion of national economic development can be a notion central to a wilderness philosophy, at least in the near future. Many wilderness values are not amenable to valuation within the context of market exchange, and there are other economic measurement problems to resolve.

Because of the limited state of the art for measuring all wilderness benefits, the need will continue to exist for some time to defend wilderness resource allocations primarily in the political arena. To do that well—and to guide wilderness management adequately—the most central wilderness values must be articulated.

Most Central Values

Of the many types of wilderness benefits we described, six seem to us to represent the core of a wilderness philosophy. Each is wilderness-dependent, historically valid, shaped by an understanding both of the realities of wilderness and of the needs of civilization, and intuitively clear (with the possible exception of the last one listed). They are:

1. Preservation of representative national ecosystems and maintenance of species diversity as laboratories for links with the past, learning, and scientific research, and as models for appreciating the complex, interactive, supportive, and competitive forces that maintain life without the need for human assistance.
2. Spiritual values that capture the themes of natural cathedrals, understanding unity and continuity, celebrating the creative forces behind life, and realizing the spiritually sustaining and cleansing powers of natural areas.
3. Esthetic values that go beyond scenic beauty to the sublime—to the notions of awesomeness, majesty, and overwhelming esthetic impact.
4. Inherent/intrinsic values which, if they do not adequately articulate, at least gently hypothesize that nonhuman organisms have their places on Earth and that perhaps even inanimate objects have the right to exist. Wilderness preservation, as a form of restraint, helps temper the tendency of aggressive humankind to conquer and subdue the entire Earth.
5. Historical and current cultural values nurtured by wilderness, such as freedom, pride in one's nation's material bounty and splendor, creative inspiration, and maintenance of a part of the past out of respect for what has been.
6. Specific types of recreational use that depend on wilderness settings, including the quest for self-sufficiency, particular types of challenge and skill-testing, and recreation and therapeutic benefits related to being in a tranquil, serene, primitive area with few other people around.

It is our conviction that these six benefits constitute the basis of a wilderness philosophy. If they are not accepted and acted upon, the remaining wilderness will fall victim to the same utilitarian pressures that have modified most of the American environment. Finally, let us emphasize that all six arguments are made the more telling by the fact of the scarcity of wilderness.

This is 1985, not 1885 or 1685. The frontier is gone. The amount of pavement in the 50 States is approximately equal to the amount of designated wilderness. There is much of which to be proud in this fact; we have indeed made the crooked straight and the rough places plain. Eliminating wilderness defined human success for thousands of years. It was what the old frontier was all about. But just as the conquest of wilderness inspired the old frontier, the conquest of civilization should inspire the new frontiersmen. It is now civilization, not wilderness, that needs taming. But we must always remember that the wilderness movement is not against civilization; it is for a satisfying, sustainable civilization. Continued investigation of wilderness benefits will help clarify this ongoing relationship. Although research is needed on all benefits, greater attention is particularly needed on the six central values, even though they are the most difficult to quantify.

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EVOLVING CONCEPTS AND TOOLS FOR RECREATION USER MANAGEMENT IN WILDERNESS: A STATE-OF-KNOWLEDGE REVIEW

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ABSTRACT

The principal use management tools and concepts now available to wilderness managers are reviewed, with emphasis on research contributions to their development. Strategies discussed include carrying capacity, recreation opportunity spectra, limits of acceptable change, and experience-based management. Contemporary issues and tools, including information and education, use limits, and monitoring and evaluation, are presented. The need for further research on these topics is noted, followed by a discussion of other important recreation management use issues that need to be studied.

WILDERNESS AND MANAGEMENT: ANATHEMA OR NECESSITY?

It was once important to debate the validity of managing wilderness. For many, management of the wilderness resource was an anathema. If wilderness is a place where the human touch is not laid upon the land, why then should it be managed? If areas are to be set aside for their wildness, then how could they be subject to the control management implies? Wilderness is a locale for natural processes to operate without the intrusion of humans, so why do these same humans speak of management? If management is defined as active manipulation and intervention, then the very essence of wilderness could be lost through the actions of wilderness managers.

Such discussions of the late 1950's and early 1960's were stimulated by the growing debate over the wilderness bill and the report of the Leopold Committee on Wildlife Management in the National Parks (1963). Stewart Udall, then Secretary of the Interior, asked a distinguished panel of scientists to review the intense wildlife management problems existing in several National Parks. The committee, informally named after its chairman, A. Starker Leopold, went far beyond its initial mandate in several recommendations. The Leopold Committee correctly concluded that many problems resulted from imprecise and inexplicit management objectives. Without such objectives, there could be no coherency or direction to any program. The committee itself suggested that National Parks remain "vignettes of primitive America," implying that such areas represent the landscape as it was when European man first inhabited the continent. Others disagreed, recommending that the objective be to allow natural processes to operate to the extent feasible: parks and wildernesses should be places where one can view the operation and effect of ecological forces unaffected by the influence of human activity.

These issues clearly involved the practical, yet critically important, issue of identifying the appropriate intent for classified National Parks and wildernesses. Whether parks and wildernesses were to be static representations of a landscape at a particular time, statements of the dynamic reality of natural processes, or esthetically pleasing vegetational mosaics was a question demanding resolution. There was no obvious answer.

Stephen Spurr (1963, p. 73), an ardent spokesman for management as intervention, proposed:

> ...we can continue our present practice of interfering in a limited extent to control fire, spray insects, regulate hunting pressure in wilderness areas, to fish and to regulate water supply. I believe, however, that we should take a more forward looking and constructive view and manage the forest itself skillfully, silently and inconspicuously to modify the forest ecosystem so that it most nearly approximates those types which are desirable from man's viewpoint.

Macinko (1970, p. 239) felt that the issue was really one of degree:

> No doubt the wilderness purist will recoil from the suggestion that wilderness should be managed, but I find no quarrel with some degree of wilderness management—a practice already engaged in—though I would brook far less than Spurr.

This debate unambiguously illustrated how social and cultural values mold the interpretation given to biophysical phenomena. What a park or wilderness is reflects the dominant social view of the day. In periods of social change, more than one interpretation may exist, and such interpretations are often conflicting. Yet, these areas are administered by managers who need clear direction and appreciation of the values represented by classification to effectively and consistently carry out socially acceptable actions.

The recognition generally prevails that management is needed in wilderness, though how much management and what technologies are appropriate are still debated. Immediately following the passage of the Wilderness Act in 1964, the question of how much and what kind of management rose to confront the Forest Service task force formed to write administrative policy for wilderness management. Roth (1984) details how the task force had to deal with the management issue and notes that this task force debated not only the issue of nonconforming uses in wilderness but also the issue of how much management would be permitted. In essence, the task force

adopted a "strict constructionist" perspective—if the Wilderness Act did not specifically allow or except a nonconforming use, then the agency would not permit that use in wilderness. A broader interpretation of management opportunities is now taken by the Forest Service.

Several conservation groups have also expressed concerns about the intrusiveness of management technology used to address wilderness management problems. For example, in its recent policy statement, The Wilderness Society recognized the importance of maintaining the wilderness with light-handed techniques:

> Managers should use only those tools, structures, equipment or practices that are the *minimum necessary* to protect the wilderness resource (Frome 1985, p. 225).

Such groups also worry about maintaining a resource which provides "outstanding opportunities for solitude or a primitive and unconfined type of recreation" as originally stated in the Wilderness Act, strongly reinforcing the recognition that the wilderness resource is, in part, an experience, which can be satisfied with only minimal disruptions by management.

It is now widely accepted and recognized, even among environmental groups, that wilderness uses must be managed in order to ensure that the "enduring resource of wilderness" Congress mandated in 1964 is not lost. Zaslowsky (1984) admitted that "the time has long passed when a wilderness area could be legislatively designated and then left alone to the birds and the beasts and the wind."

Indeed, the realization that wilderness must be managed is now not only widely recognized, but also pressed by increasing numbers of groups and individuals. For example, the theme of the National Wilderness Management Conference held in fall 1983 (Frome 1985) was "Keeping What We've Got." And, in their comprehensive study of wilderness managers, Washburne and Cole (1983) clearly identify the need for management of wilderness: over 70 percent indicate that human impacts to vegetation are a problem; 60 percent feel that they have a littering problem; and while over half the managers report no social impact problems, most indicate that recreational use exceeds capacity at least in some places within their wilderness.

The biophysical aspect of wilderness itself often needs little in the way of management, other than to ensure that natural processes are allowed to operate in an untrammeled way. With the possible exception of prescribed, scheduled fire ignitions, there are few explicit actions managers can take to modify the biophysical setting to enhance or maintain wilderness values. However, it is management of the human uses of wilderness, both those identified as compatible and those which are excepted and nonconforming, which has risen to the forefront of concern among environmentalists and managers alike. Essentially, the issue is how much management can wilderness use receive within the philosophical traditions briefly alluded to above?

Such questions become even more difficult to answer for some of the newer, eastern areas included in the National Wilderness Preservation System. For example, the 10,000-acre Indian Mounds Wilderness in east Texas contains roads, oil wells, pipelines, active timber harvest and insect control projects, powerlines, motorboat access, and several other conflicting and nonconforming land uses. How is the wilderness manager to maintain or restore wilderness values when confronted with such an array of uses? How can the manager relate the philosophical traditions of wilderness values to mitigating impacts from these types of uses?

In this paper we review research relating to the principal use management concepts and tools available to wilderness managers. We do this by using research studies to show how wilderness use research has evolved over the past 30 years and especially how it has been related to a search for frameworks to guide management. Our focus is on reviewing research dealing with management of recreational uses rather than on other acceptable or nonconforming uses because, over the wilderness system as a whole, recreational uses provide the major management challenge (Washburne and Cole 1983). There are literally dozens of specific management actions that could be developed in reaction to a particular wilderness problem. Our focus here is on concepts and principles that a manager can use to address wilderness management rather than on description of specific actions, such as campsite obliteration, rehabilitation, or closure. The literature well documents such actions, and several papers reviewed here also address the range of potential actions.

We begin with a look at the evolution of strategies for planning and management such as carrying capacity-based management, the Recreation Opportunity Spectrum and Limits of Acceptable Change processes, and experience-based management. This discussion is followed by a look at research on three contemporary issues—information, use limit policies, and monitoring/evaluation—to illustrate the range of topics being studied and/or needing study today. We conclude by listing some topics that we perceive need study if wilderness management is to be enhanced and if its techniques are to gain legitimacy.

STRATEGIES FOR MANAGEMENT

Essentially two strategies for managing wilderness resources have developed: emphasis on resource protection and emphasis on opportunities for recreation experiences. While we view these as two legs of an integrated management strategy, they often have been separated with arguments made for the rightness of one strategy over the other. We will not repeat this debate. The Wilderness Act (1964) clearly suggests that both resource protection and providing opportunities for primitive and unconfined forms of recreation (an experiential phenomenon—see Driver and Tocher 1970 and Brown 1983) are responsibilities of wilderness administrators.

What is the difference between the two strategies? A strategy for resource protection, emanating from historical concerns about fire protection and human waste and litter (see Dana and Fairfax 1981) and contemporary concerns about environmental quality, preservation of heritage, and preservation of biological stocks, focuses on managing uses, natural phenomena, and impacts to ensure an enduring wilderness resource. In contrast, a strategy for experience-based recreation management, stemming from consumer sovereignty and contemporary concerns with the human condition, focuses on managing uses, natural

phenomena, and impacts to provide opportunities for primitive and unconfined forms of recreation. Note that the objects of management are the same while the purposes differ. It is our observation that wilderness research and management have been evolving to integrate both of these perspectives. The discussion that follows should reveal this evolution.

Early Research

Much of the early research (1960-70) regarding wilderness management focused on describing uses, users, and impacts. There was a need to know who was doing what, and where and when they were doing it.

Though not research in the classical sense, Snyder (1966) reported his observations of 14 years of management issues in the John Muir Wilderness. He noted the problems of trails, camping debris, campsites and their dispersal, forage for recreational stock, use of timber by recreationists, administrative sites, use and overuse, and how use might be limited. While not specifying a management scheme, his observations clearly pointed out many of the challenges in wilderness management and led to recognition that research and management were needed in wilderness.

For these early years we might ask, what was done that has been useful in managing either the wilderness resource or the users of wilderness? In the 1960's the Boundary Waters Canoe Area (BWCA) and the larger Quetico-Superior area were under considerable study by Forest Service researchers. This research was pioneering, and the questions asked are still relevant. How are the areas being used; how is wilderness perceived by different types of users; how do use and perceptions of different areas compare? Overriding these questions were concerns about how resources and users were to be managed so that the resource base could be maintained and opportunities for desired experiences provided in the face of rapidly increasing use. Lucas' work was vital for answering these questions. He examined the distribution of all forms of use of the Quetico-Superior area by different types of users and projected future use (Lucas 1964a), related such information to the emerging management concept of carrying capacity (Lucas 1964b), drew implications for management of the various concepts of wilderness held by different kinds of users of the area (Lucas 1964c), began to characterize the changes occurring in recreational use (Lucas 1967), and compared use of the Quetico-Superior area to the Algonquin Provincial Park (Lucas and Priddle 1964). Not only was this work valuable in developing management strategies for the Quetico-Superior area, but it laid a foundation for subsequent research by Lucas and others in other areas.

At about the same time, other researchers were doing equally significant research that would prove helpful to management. Burch (1966) reported on the effect of life-cycle recreational choice, pointing out the changing behavior of recreationists as life cycle progresses. His data showed that remote-camping (wilderness) families represent those just beginning their families and those whose children are leaving home. Merriam (1964) had completed a study of the socioeconomic value of the Bob Marshall Wilderness in Montana, concluding that in 1960 the public interest was best served by reserving the Bob Marshall as wilderness. And Heinselman (1965) was identifying vegetation management possibilities in wilderness and primitive areas.

Toward the end of the 1960's, the Hendee and others (1968) research on wilderness users in the Pacific Northwest was significant. They studied users of three different areas—the Glacier Peak Wilderness, described as a backpackers' area; Oregon's Three Sisters Wilderness, which was a day-hikers' area; and the Eagle Cap Wilderness, which they identified as favored by horse users. The study combined a look at user characteristics and attitudes with identification of preferences for management strategies and actions. The significance of this study, for our purposes, is that it was fairly comprehensive, it identified the location of users along a wildernism-urbanism scale, and it focused on management issues. Among the many findings of the study were: those who were more wilderness purist in their orientation often held different attitudes than not-so-purist recreationists; users of all three areas, though different in their style of wilderness recreation, held quite similar attitudes about management; and the facilities and development interests of many users were not consistent with Wilderness Act specifications. Based on this research, the questions for management are many. How might we handle the development preferences of users in view of the restrictive requirements of the Wilderness Act? Can we manage similar areas with users participating in different styles of wilderness recreation? Whose opinions are to count in management decisions since groups differ in their attitudes and preferences? Also, to what extent do managers perceive accurately the management directives and needs visualized by users?

Hendee and Harris (1970) followed up on this last question and concluded that managers correctly perceived user preferences for many issues, but did differ on some critical issues dealing with behavior, development, and the prevalence of purist philosophies. In a sense, the findings suggest that users are much more flexible regarding management issues than was originally hypothesized.

In another major study Stankey (1971, 1973) examined the characteristics, behaviors, attitudes, and management preferences of users of four wilderness areas—the High Uintas Primitive Area, the Bob Marshall and Bridger Wildernesses, and the Boundary Waters Canoe Area. Much of the focus was on carrying capacity and how one might manage to achieve use within capacity. Later in this paper the carrying capacity aspects of this research are discussed. Here, however, it is appropriate to highlight an attitudinal measurement aspect of the research. Stankey developed a wilderness purist scale to measure how Wilderness Act values were like values of individual wilderness recreationists. His was a multidimensional scale patterned on statements from the Wilderness Act.

Related to this scaling effort was a desire to identify a group of users whose opinions about carrying capacity, management, and wilderness should count. Stankey (1971, p. 274) said:

> By selectively considering the attitudes and perceptions of a population which has the most highly developed appreciation of wilderness values recreation use may be maintained at a

level consistent with the preservation objectives of the Wilderness Act while also insuring the availability of a high quality wilderness experience. Thus, in examining the question of wilderness recreation carrying capacity, we will focus attention on the strong purists.

An outgrowth of this particular aspect of Stankey's work was a workshop to explore the issue of whose opinions should count in management decision making (Royer and others 1977).

Another area of research that developed fairly early was methodological and dealt with estimating use, identifying spatial and temporal distribution of use, and determining how best to obtain survey information from users. In the area of estimating use, the work of James and others is illustrative (Wenger 1964; James and Henley 1968; Lucas and others 1971). They tested methods of estimating use, including testing the effectiveness of unmanned registration stations and automatic counting devices. Conclusions from this work were that trail registration, when used with regression or ratio estimation procedures, could be calibrated and used to accurately estimate use, and that trail registration would have other benefits in dispersing information to users and collecting information about users and their behavior.

When considering the spatial and temporal distribution of use, the work of Lucas stands out. Much of his work in the Quetico-Superior area described use patterns, including the timing of use and the distribution of use over launch sites, portages, and lakes (Lucas 1964a).

In the area of obtaining valid and reliable survey information, several studies were undertaken dealing with nonresponse bias (Wenger and Gregersen 1964), situational and voluntary response bias (Peterson and Lime 1973), and the appropriate person(s) in the recreational group to interview (Jubenville 1971).

One other area of pioneering research needs to be addressed. In 1970, Lucas (1980) began a series of studies that culminated in a comparison of use patterns and user information across nine different areas. Essentially what began as establishment of baseline surveys for individual areas became a comparative baseline across different types of areas, mostly in the Northern Rockies but also including the Desolation Wilderness in California. This baseline information on users, their behavior, and their perception of the resource enables researchers to measure changes in use and the resource for individual areas. At the same time, since the same baseline information is available for several areas, one can compare conditions across areas and changes across areas over time. It enables putting each area into a broader context, detecting changes unique to one area, and trends in use and resource change over the broader wilderness system.

From a somewhat later period one other piece of literature stands out because it is one of the first to focus on an Eastern wilderness (Leonard and others 1978). The purpose was to describe use characteristics for New Hampshire's Great Gulf Wilderness. In looking at use and its distribution over the area, the study followed much of the pattern of early wilderness research in the Midwest and West.

A lot of stimulating research done from the late 1950's to the early 1970's laid a foundation for subsequent effort at describing the wilderness recreation phenomenon and developing ideas about the management of recreation in wilderness. The research pointed out the need to know much more, and it made it clear that if resources were to be protected, desired experiences were to be realized, and budding conflicts among users were to be reduced, a framework for management of recreation in wilderness was necessary.

Carrying Capacity—Search for a Holistic Management Framework.—Much of the research already identified dealt with the management concept of carrying capacity (Lucas 1964b; Snyder 1966; Stankey 1971, 1973). Carrying capacity was a concept being applied to nonwilderness recreation as well (Wagar 1964), but it seemed well suited to the wilderness situation where there were rather specific concerns about preservation of natural resources and delivery of specific recreation opportunities.

In this context, Lucas (1973, p. 150) indicated that "wilderness cannot survive the draw-a-line-and-leave-it-alone philosophy." It required management focused on its unique qualities to ensure that it was perpetuated. To that end, Lucas (1973) developed a framework for management that was formulated from much of the early research on recreational carrying capacity. In his framework he identified several management principles: (1) maintaining basic ecological processes, (2) controlling visitor impacts, (3) developing the opportunity spectrum, (4) managing the wilderness periphery sensitively, (5) respecting visitors' freedom, and (6) providing opportunities for solitude. Implementing these principles required a holistic view of wilderness management—just the kind of view that the recreational carrying capacity concept was beginning to foster.

One early conclusion was that "the 'preserve' and 'use' dichotomy of the Wilderness Act has created a situation that leaves virtually no alternatives for the wilderness manager to consider other than establishing some 'carrying capacity' for wilderness" (Stankey 1972, p. 98). Wilderness carrying capacity was looked at as deriving from two components, ecological and sociological carrying capacity. Determining ecological carrying capacity would involve investigating changes in the physical-biological aspects of an area due to both natural and human-impact causes; determining sociological carrying capacity would focus on the effects of use on user satisfaction. While these two considerations make up the concept of wilderness carrying capacity, they often have been treated independently by researchers.

From the research on carrying capacity we have learned a lot about both people and management. We will not be able to review all of what has been learned here, but we will try to illustrate some of what has been learned and how that relates to wilderness management.

Lucas' (1964b) work in the Quetico-Superior area set the pattern for much of what was to follow regarding the sociological aspects of carrying capacity. Work by Frissell and Duncan (1965) and others launched the studies of ecological carrying capacity in the wilderness.

Social Carrying Capacity.—Exploring the relationships between environmental variables (social and physical-biological) and peoples' response has been the primary topic of research on social carrying capacity. Much of the emphasis has been further narrowed to the relationship between satisfaction and the number and type of encounters among users.

For example, one outcome of Lucas' (1964b) study was the clear indication that recreationists following different styles of wilderness recreation see issues of crowding and capacity differently, and they use areas differently too. He noted that motor canoeists were less sensitive to crowding than paddling canoeists, and that other motorboaters were even less sensitive to crowding than motor canoeists. He also found that there was differential penetration of the Quetico-Superior area by canoeists, motor canoeists, and motorboaters. This research, from which one might conclude that there are different sociological carrying capacities based on the goals of various groups, established a pattern for looking at the amount, frequency, location, and mode of transport aspects of interactions among recreationists as a way to develop information about perceived crowding (over-capacity use) and its effect on satisfaction.

Stankey's (1971, 1973) research extended this look at differential perceptions of crowding to mountain wilderness areas. From his surveys he found that, in general, users expressed satisfaction with having no contacts with other backpackers while having as few as four contacts was bothersome to 80 percent of the users. There was some differential effect due to style of recreation, with horse user parties somewhat less acceptable than backpacking parties. Stankey also noted that there were perceived effects associated with location of encounter and size of group encountered. He found that interaction along the periphery of wilderness areas was expected and thus more acceptable, and that large groups, which are not the norm in wilderness, had a disproportionately negative effect on visitor satisfaction.

These results were generally replicated in Badger's (1975) study of users of the Rawah Wilderness in Colorado. He went a step further, however, and also determined tolerance levels for encounters between user groups. What he found was that users were willing to tolerate more other groups than they preferred to encounter at a ratio of about 2:1. One might ask, why are they willing to tolerate more than they prefer and still perceive themselves as having a satisfying recreation experience? Satisfaction obviously is a complex concept and several factors contribute to it. First, Stankey (1971, 1973) demonstrated that some encounters are desirable for most wilderness users. For example, for most users one or two encounters are preferred over no encounters. Second, Shelby and Nielsen (1975), studying users of the Colorado River in the Grand Canyon, showed that some measures of satisfaction (trip quality) are unrelated to actual encounter levels in some situations. This finding has also been shown by Greenleaf and others (1984) in the White Mountains of New Hampshire. Third, Badger (1975) found that environmental damage and inappropriate behaviors are much more disturbing to users than encounters with others.

This third finding was extended by Harris (1978) in his study of crowding and satisfaction in the Rawah Wilderness. His findings suggested that several factors regarding the behavior of others have a greater effect on satisfaction than do encounters, even encounters with large groups or groups on horseback. From this we might conclude that the relationship between encounters and satisfaction is not linear. Encounters are not the sole, nor often the most important, factor in determining the sociological carrying capacity, a point very clearly made by Lee (1977). In fact, in one case Manning and Ciali (1980) showed that there is no relationship between reported increases in number of users and overall satisfaction rating. If encounters are important, then, their importance must vary with the location of encounter, the style of activity, the type of group encountered, and the saliency of encounters (Stankey and McCool 1984).

From research by Stankey (1980) we also learn that tolerance for encounters varies among wilderness areas. He compared the heavily used Desolation Wilderness with the more lightly used Spanish Peaks Primitive Area and found that Desolation users were more tolerant of higher levels of encounters; their satisfaction with their experience was maintained at higher levels of encounter. Greenleaf and others (1984) found a similar phenomenon in New Hampshire. Thus, while wilderness users are similar in their attitudes toward many things (Hendee and others 1968; Stankey 1971, 1973, 1980), they are not necessarily similar in their attitudes toward appropriate or tolerable encounter levels.

This research on encounters was designed to explore a major factor of sociological carrying capacity. We have learned from it a lot about both what people say and do in wilderness. But, by itself, it relates to only part of the carrying capacity question because it ignores wilderness resources.

Ecological Carrying Capacity.—We also have learned about ecological (resource-focused) carrying capacity in wilderness. Much of the work in this area, like the work on social carrying capacity, has focused on problems and potential problems rather than solutions, but recently there has been some work on solutions.

Frissell and Duncan (1965) clearly showed how campsites in the Boundary Waters Canoe Area were becoming denuded of vegetation and that erosion, soil compaction, and root exposure were serious problems on many sites. These problems, especially vegetation reduction, occurred fairly rapidly and with only light use. Merriam and Smith (1974) found that most ground cover and soil impact occurred during the first two seasons of use for Boundary Waters Canoe Area campsites.

Trail impacts similarly are most related to the first users; subsequent users usually follow established paths and cause erosion once the first users denude the trail (Helgath 1975). On Maine islands, however, even though ground cover vegetation was removed by trampling, there was little measurable trail formation, erosion, or soil compaction (Leonard and others 1985). As one might expect, there are differential effects by hikers and horseback users, with hikers generally less damaging. Research also has focused on effects of use on water quality with the

general finding that, even in high-use areas, pollution from human sources is not a significant problem (Aukerman and Springer 1976; Werner and others 1985).

In the last few years Cole (1981, 1982, 1983) has reported research that describes both the type and extent of vegetation and soil impacts and suggests what might be done about them. One of his conclusions is that dispersal of use may not be a feasible way to reduce problems; in fact, he says more problems are created. Since most damage occurs from a small amount of use, dispersal simply compounds the problem. He recommends confining the impact to as small an area as feasible and living with the resulting site impact. Another conclusion from his work is that many campsite closures are not very effective in rehabilitating campsites because of slow rates of natural recovery, poor compliance by users, and failure to actively assist revegetation. Techniques such as soil scarification, seeding, and transplanting can positively affect recovery (Cole and Schreiner 1981), but, even with increased recovery, another problem was noted at the Big Creek Lake site (Montana): new campsites were created near the closed sites, effectively expanding the area of impact (Cole and Ranz 1983). While closures with revegetation assistance might improve isolated areas over time, one must consider the possibility of negative effects from the closures, especially the expansion of disturbed area. At Big Creek Lake, for example, closure of campsites caused the disturbed area to increase by 50 percent. Cole's results characterize what might be likely in many Western wilderness areas where the summers are relatively dry. Experience in parts of the East, however, suggests that rehabilitation of some sites might be more successful. For example, Leonard and others (1985) found on Hurricane Island, ME, that most species, given a 1-year recovery period, were able to withstand low levels of trampling stress. Ketchledge and others (1985) found that it was possible to reestablish alpine vegetation on the summits of the high peaks in the Adirondacks.

Moving Toward a Management Framework.—From these and other studies of social and biological aspects of carrying capacity we have learned about managing users and the resource. Such studies, however, could have been done without the concept of carrying capacity. One could simply have looked at satisfaction or effects on the resource and not tried to cast such effects in a broader context. This broader context seemed needed, however, to provide an organization and structure for wilderness management that would help managers ask questions about the multifaceted aspects of wilderness use and management. The search was for a holistic management framework to tie the pieces together, especially in the face of increasing use, resource impacts, and complaints about crowding and the reduction of the "wilderness experience."

While researchers recognized both the fallacy of deriving a single carrying capacity value (Lucas 1964b) and that there were problems in the direct transfer of carrying capacity concepts to management (Burch 1981; Wagar 1974), the ideas spawned from discussions of capacities and how they might be identified led to modeling the greater management system (Brown 1977a; Heberlein 1977; Stankey 1972). Stankey's model specified the kinds of information necessary to arrive at carrying capacity and the kinds of management responses to ensure use and impact within carrying capacity (fig. 1). Brown's model took a somewhat different focus and pointed out the place of carrying capacity determination within the major management decisions that must be made to arrive at a sound management program (fig. 2). Heberlein's model specified the process of arriving at a carrying capacity, and in so doing identified the role of management objectives, visitor assessment, and normative assessment in the management process. He clearly pointed out that satisfaction is not the sole criterion for establishing social carrying capacity. Specifying management objectives, examining user behavior, assessing user perceptions and preferences, and uncovering the norms that users express regarding use levels and encounters are each necessary in determining social carrying capacity.

Work on clarifying carrying capacity and its relationship to planning and management has continued, with notable achievements by Leonard and others (1977), Shelby and Heberlein (1986), and Graefe and others (1985). Leonard and others (1977), in developing a design capacity system, focused on many of the issues noted by Brown (1977b) and Heberlein (1977). They developed a system of assessing capacities that focused on future usage, facilities, and maintenance as factors that managers could control. Their contribution is an emphasis on designing for capacity rather than accepting carrying capacity as given. Shelby and Heberlein (1984, 1986) show the normative nature of carrying capacity analysis and the relationships among use, management, and impact parameters. Graefe and others (1985) cast their formulation into a management planning framework similar to the Recreation and Wilderness Opportunity Spectra and Limits of Acceptable Change frameworks described in other sections of this paper.

Estimating Carrying Capacity.—Attempts to actually estimate a carrying capacity have been few, though use limits have been imposed by management. Greene's (1976) study in the Rawah Wilderness, however, did illustrate what might be done.

Using the decision model described by Brown (1977a, 1977b) and Brown and others (1976), Greene demonstrated how user preference, resource capability, administrative, and current use information could be used in developing management objectives that, when combined with the physical structure of an area, would be the basis for deriving carrying capacity. Here are the general steps he followed (Greene 1976, p. 37-38).

1. Formulation of management objectives by weighing information concerning people's preferences, resource capabilities, institutional directives, and the existing situation.
2. Inventory of wilderness area's physical system structure—the physical capacity.
3. Using the physical capacity as a base (which includes information concerning user facilities and the area's physiographic character) determine what areas are acceptable for recreational use by overlaying the social and biological management standards.

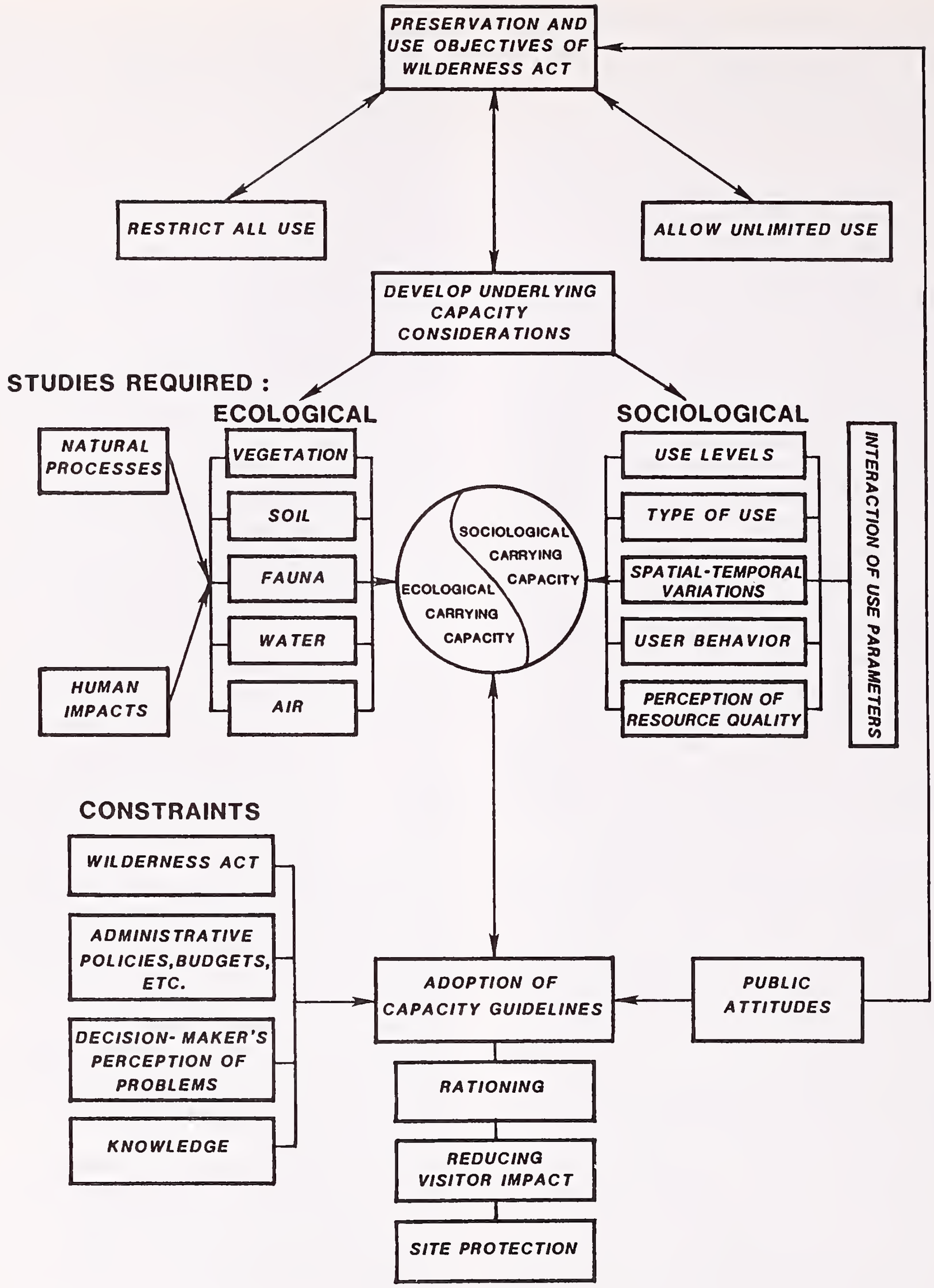

Figure 1.—Stankey carrying capacity model. Source: Stankey (1972).

4. Calculate carrying capacity by estimating the number of people or parties that may use these "acceptable" areas for recreation at any one given time.

This process was applied to the 27,000-acre Rawah Wilderness near Fort Collins, CO. Two management objectives, one specifying acceptable social conditions and the other specifying acceptable physical-biological conditions, were drafted. The resources were mapped noting vegetative and soil conditions and campsite characteristics (especially visibility of other campsites). In this example, campsites were considered the critical determinant for carrying capacity. Thus, using the management objectives and the physical inventory of campsites, carrying capacity was calculated. Greene (p. 56) indicated, "This is done by using the physical capacity data as a base, and then determining which sites meet the biological and social standards specified in the management objectives." He also made the point that "judgment plays an important role when making these initial selections, and modifications in the number of available sites may be necessary if it is found that there are too many parties at a lake or if there is room for more parties without exceeding the standards" (p. 57). The result of his analysis is in table 1.

One should note that these capacity limits are specific to the management objectives articulated and to the management conditions that existed at the time of Greene's study.

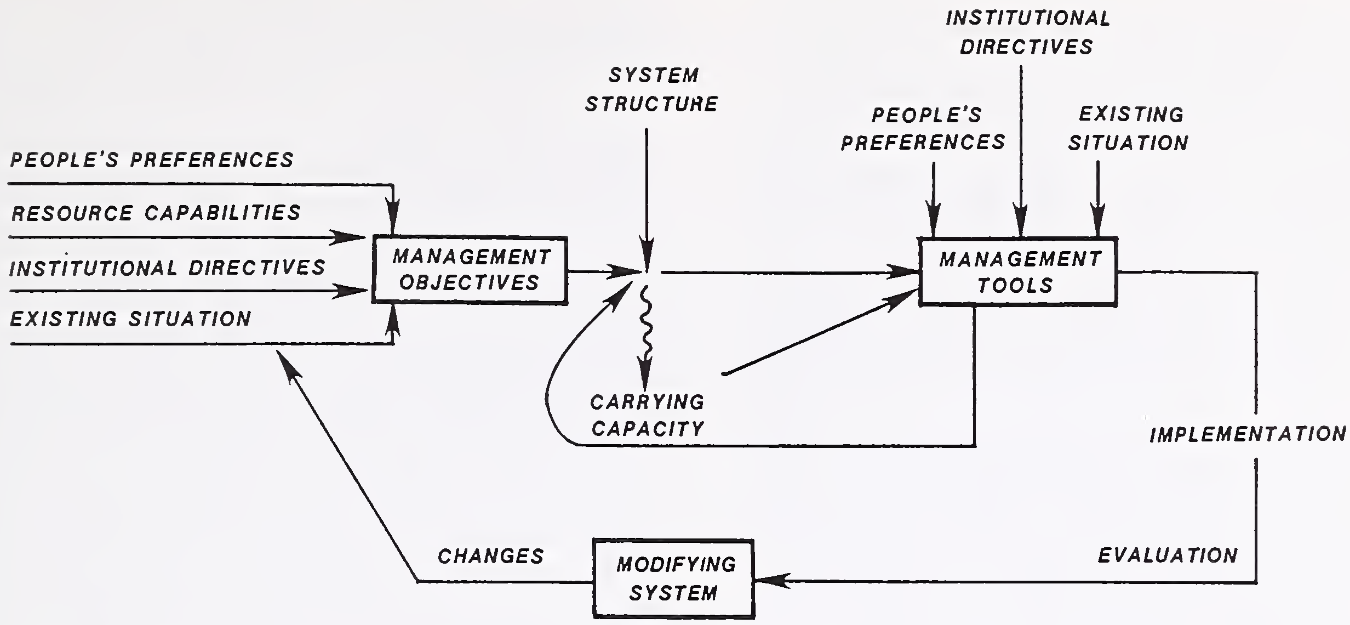

Figure 2.—Decisions with their inputs and outputs for a carrying capacity-based management system. Source: Brown (1977b).

Table 1.—Number of campsites conforming to management objectives that are available for different sized parties[1]

Sector of Rawah	Number of available campsites[2] 1-2 hikers	3-5 hikers	6+ hikers
1	2	3	1
2	29	12	1
3	55	26	15
4	25	9	9

[1]Source: Greene (1976, p. 64).
[2]All sites can be used by parties of one or two hikers, only sites in columns 2 and 3 can be used by parties of three to five hikers, and only sites in column 3 can be used by parties of six or more hikers.

He noted that other factors, such as seasonal considerations and different management practices, would result in different capacities. This is consistent with the Leonard and others (1977) notion of design capacities. Greene (p. 69) also cautioned that "the process of calculating carrying capacity is a means to the end of protecting a most precious, irreplaceable resource, and a most precious, irreplaceable experience." Calculating carrying capacity is not the end; it is the generation of one bit of information that might be useful in making subsequent management decisions.

Calculating carrying capacity is especially useful because it demands a holistic look at users, the resource, and management. It requires a model of the wilderness management system and thus proposes a process that requires the manager to focus on a multiplicity of relevant management questions. The research on carrying capacity has been largely a search for a holistic management framework. As we shall observe, it has helped lead to other useful concepts for planning and managing use of wilderness areas. It has helped us expand our focus beyond the "how much is too much" notion of carrying capacity to broader planning, management, and impact questions.

Recreation and Wilderness Opportunity Spectra

Some of the research on carrying capacity and the models of management suggested by Brown, Heberlein, Leonard, Lucas, and Stankey focuses attention on management objectives that specify the kinds of preservation and recreation use opportunities to be provided by management. This attention evolved to incorporate concepts of Recreation and Wilderness Opportunity Spectra in wilderness management.

Adapting the idea of a Recreation Opportunity Spectrum (ROS) to an operational planning and management framework has been useful for fitting recreation into multiple-use land management, including management of recreation in wilderness (Buist and Hoots 1982). The ROS is a framework for characterizing resource and visitor management aspects of the recreation phenomenon, especially characterizing the type, quantity, and quality of recreation opportunities.

As a concept for management, the ROS has been around for some time. The notion (though not necessarily the label) occurs in the writings of Marshall (1937), J. V. K. Wagar (1951), Burch (1964), Lucas (1964c), and J. A. Wagar (1966) among others. What has been suggested is that a diversity of recreation opportunities is needed to satisfy the desires of a heterogeneous public.

In the late 1970's, management need and research results came together in support of developing an operational ROS planning framework. To integrate recreation into land management planning under the National Forest Management Act (PL 94-588) and the Federal Land Policy and Management Act (PL 94-579) required something different than what we were then doing and ROS was proposed as a solution (Brown and others 1978; Driver and Brown 1978). At the same time, it was observed that management often changed recreation settings without a

clear recognition of the consequences, and ROS was proposed as a solution to this problem (Clark and Stankey 1979). The outcome of these realizations was development of an operational ROS planning and management framework (Stankey and Brown 1981) that was adopted nationally by both the Forest Service and the U.S. Department of the Interior, Bureau of Land Management (Buist and Hoots 1982).

Research supporting development of an ROS was extensive. Burch's (1964) examination of collective aspects of recreation behavior, Lucas' (1964c) study of perception and use of the Boundary Waters Canoe Area, and Shafer's (1969) confirmation that the average camper does not exist all point to existence of recreational diversity. Studies of the desires for different types of experience by hunters (Potter and others 1973), anglers (Driver and Knopf 1976), river runners (Schreyer and Nielsen 1978), and wilderness users (Brown and Haas 1980) indicate that a diversity of opportunity is needed within and between recreation activities. Research by Peterson (1974), Allen (1979), Harris (1978), and others has confirmed that attributes of the recreational setting vary in importance for different individuals. Finally, Brown and Ross (1982) and Manfredo and others (1983) have shown a linkage among recreation activities, settings, and desired experiences, thus helping to tie together the notion that what people do, who does it, where they do it, and what they desire to get from doing it are important in planning for recreation use.

ROS Process.—The ROS has provided a clear distinction of the products of recreation management, recreation opportunities, and a process for integrating these products into land management planning. Building on the realizations that recreationists seek opportunities to: (1) participate in certain activities; (2) recreate in certain settings; and (3) realize specific experiences, one task of the recreation planner and manager "...is to formulate various combinations of activity and setting opportunities to facilitate the widest possible achievement of desired experiences" (Stankey and Brown 1981, p. 65).

This task is facilitated by the planner: (1) estimating demand for specifically defined recreation opportunities, (2) conducting a resource capability analysis to estimate potential for supplying various recreation opportunities, (3) identifying which recreation opportunities are currently provided, (4) determining where and how different recreation opportunities can optimally be provided, (5) integrating recreation opportunity recommendations with recommendations for other resource outputs, (6) developing alternative plans for resource allocation, (7) developing recreation action and project plans that are consistent with the allocation chosen, and (8) implementing plans and monitoring and evaluating the success of the implementation.

For managers, the outputs of ROS planning are: (1) specific management objectives for tracts of land that suggest the kind of recreation opportunity to be provided on each tract, (2) standards indicating acceptable conditions of elements of the recreation setting for each recreation opportunity, and (3) guidance for selection of appropriate management tools to be employed in meeting the management objectives. These outputs can be incorporated into either written or mapped plans to indicate to the manager what should be done to ensure meeting the recreational needs of target user publics.

ROS in Wilderness.—In the context of wilderness management, at least three uses have been made of the ROS. First, ROS has been used to make a clear distinction between the activity of recreation and the wilderness resource. That is, it has been used to make it clear that these are two different phenomena and that the manager's consideration of each must consider their differences. For example, we find some managers identifying primitive and unconfined forms of recreation only within wilderness while recreationists do not make such a narrow identification. Also, some managers have argued that the only kind of recreation in wilderness is primitive and unconfined. The point that the ROS framework makes is that wilderness areas and recreation opportunities are different things. Both designated wilderness and nonwilderness (roadless) areas can provide primitive and unconfined recreation. Because of the politics of wilderness designation, use patterns, and other factors, many places in wilderness, such as the lower reaches of the Eagles Nest Wilderness, the Crater Lake zone of the Maroon Bells-Snowmass Wilderness, and parts of some Eastern wilderness, provide recreation opportunities that are not generally defined as primitive and unconfined.

Second, ROS has been used to indicate the types of recreation opportunities currently existing in different parts of wilderness areas and the types that should exist in the future. The general primitive and semiprimitive recreation opportunity classes of the Forest Service and Bureau of Land Management often have been subdivided to characterize more finely defined opportunities so that management prescriptions could be more narrowly written (Stankey and others 1985).

Third, ROS has been transformed into a Wilderness Opportunity Spectrum (Haas and Plisco 1979). This transformation of the ROS idea suggests that all aspects of wilderness management, including recreation, wildlife, water, fire, and scientific use, can be prescribed after considering the conditions of the wilderness that need to be maintained or enhanced to provide a variety of opportunities. In essence, the general structure of the ROS framework, definition of opportunities, identification of relevant indicators of opportunities, and specification of acceptable standards for those indicators have been extended to develop management prescriptions for wilderness and its many aspects. An example of this has been carried out in the Maroon Bells-Snowmass Wilderness in Colorado.

Limits of Acceptable Change

As we have seen, both Greene's (1976) carrying capacity-based identification of desired conditions of the social and physical-biological systems and the development of a Wilderness Opportunity Spectrum suggest that some conditions are and other conditions are not acceptable in wilderness. This theme was well articulated by Frissell and Stankey (1972, p. 173) when they asked, "What are the 'limits of acceptable change' beyond that variation expected in a natural system?" They went on to describe a

model of the "limits of acceptable change" in wilderness ecology which, in its current form, has become a model for clarifying the issues and making carrying capacity operational.

For some people the focus on carrying capacity, which was described previously, led to asking the wrong questions. Too much seemed to be focused on generating use limits and then assuming that regulation of use would solve problems of impact. But, as Stankey and others (1984, p. 34) noted, there is not "...a clear and predictable relationship between use and impact." Since there are so many factors involved in the relationship between use and impact on both the resource and experience, rather than asking how many users we should have, attention has turned to asking what conditions we want to have. This question was inherent all along in the goals of wilderness management and the articulation of management objectives, but was not being clearly asked when we were searching for a numerical carrying capacity.

The fundamental idea behind the Limits of Acceptable Change (LAC) is straightforward (Frissell and Stankey 1972). When looking at environmental conditions we should ask: What change beyond the natural variation in rate and character of change is acceptable? At what point does human-caused change alter unacceptably the character of the ecological system? Similar questions can be asked about change from what is defined as the pristine wilderness experience. What is tolerable; what is intolerable? To implement the LAC framework one needs to identify the conditions that are acceptable and establish the range between acceptability and unacceptability as the LAC.

Stankey and others (1984, p. 34) indicated that this

> ...shift in focus from "how much use" to "how much change" carries with it two important implications. First, it directs attention from use level as the key management concern to the environmental and social conditions desired in wilderness.
>
> The second implication of the LAC management framework is that it clearly places the issue of capacity in a prescriptive as opposed to technical context.

In summary, Stankey and others (1985, p. 2) indicated that "...the process requires deciding what kind of wilderness conditions are acceptable, then prescribing actions to protect or achieve those conditions."

A nine-step process has been defined for implementing LAC as a management framework for wilderness (Stankey and others 1984, 1985). This process parallels the Forest Service land management planning process. The LAC process is:

1. Identifying area concerns and issues
2. Defining and describing wilderness opportunity classes
3. Selecting indicators of resource and social conditions
4. Inventorying resource and social conditions
5. Specifying standards for resource and social indicators
6. Identifying alternative opportunity class allocations
7. Identifying management actions for each alternative
8. Evaluating alternatives and selecting an alternative
9. Implementing actions and monitoring conditions.

Specific research focusing on this framework is just now getting under way; there is not yet a validation of the framework's usefulness for managing to ensure resource protection and delivery of opportunities. Nonetheless, Stankey and others (1985) were able to illustrate how the system could be implemented for the hypothetical "Imagination Peaks Wilderness." Their example provided a good illustration of the flexibility and use of the framework.

As described by Stankey and others (1985), the LAC management framework has several elements that are much more specific now than they were in the earlier discussions of carrying capacity. The first is using issues and concerns (demand side components) to drive the system. This makes clear what publics and managers see as important. Second is the idea of opportunity classes, which are an outgrowth of work on the Recreation Opportunity Spectrum (Brown and others 1978; Clark and Stankey 1979; Driver and Brown 1978; Stankey and Brown 1981). These classes define consistent conditions among the various use, resource, and management parameters involved in managing wilderness. Third is the selection of indicators of resource and social conditions. Since it would not be feasible to identify and monitor every possible condition, indicators are selected to represent the state of the wilderness system. Fourth is the designation of standards for acceptable conditions of the indicators. These standards define the LAC and are the measurable core of management objectives. Fifth, the LAC framework has been formulated to suggest continuous public involvement. Public involvement is part of all phases of deciding what we want and how we will obtain it.

This change from a carrying capacity focus to the Limits of Acceptable Change was not the result of a specific research study. Rather, it was the result of an evolutionary process of learning more about the recreation phenomenon, about management, and about carrying capacity. The ROS development noted previously was certainly a contributor to this evolution, as was the resource impact work of Cole (1982) and the manager study by Washburne and Cole (1983). As managers and researchers have tried to make the carrying capacity model operational, they have continued to seek a more complete management model; the LAC model fills that need. It is more in tune with the times when questions are asked about the quality of the resource and the experience and when users demand a greater say in management decisions. It also is a framework that fits well with the rules and regulations for implementing the National Forest Management Act. LAC is a model that more completely satisfies the search for a holistic management framework.

Experience-Based Recreation Management

The change in management and research focus from regulation of numbers of users to conditions of the resource and experience has led to a different strategy for

recreation management, labeled "experience-based recreation management" (Driver and Rosenthal 1982; Manfredo and others 1983). This strategy implies that the outcomes of recreation engagement in specific places are important. Furthermore, it implies that there is a relationship between what people do, the place where they do it, and what they get out of doing it (Driver and Brown 1978). If this is valid, then conditions of the resource and experience are important for satisfaction of recreationists. Such notions are consistent with guiding premises laid out by Wagar (1966) for recreation management and by Lucas (1973) for wilderness management. For example, Wagar said:

1. ...the sole purpose of all land management is to provide benefits for people (p. 9)
2. ...recreation, like all other human behavior is motivated by needs (p. 10)
3. ...the quality of recreation depends on how well it satisfies the needs that motivate it (p. 10).

Given these ideas, the prescription for management would be to provide quality recreational opportunities that facilitate the fulfillment of recreationist needs. Lucas' (1973) principles for managing wilderness (cited previously) lead to the same management prescription. Finally, looking at these implications from another perspective we find that they are consistent with behavioral definitions of recreation (Brown 1983; Driver and Tocher 1970). Driver and Tocher indicated that recreation is a type of human experience that is based on intrinsically rewarding voluntary engagements during nonobligated time. This definition emphasizes the rewards or outcomes of participation in recreational activities, and thus visualizes experience as the central feature of recreation. With this definition the condition of the experience must be a focus of management.

What is experience-based recreation management? Very simply, it is management of resources and people "...which will increase the probability that specified types of satisfying experiences can be realized" (Driver and Rosenthal 1982, p. 34). With this strategy, managers attempt to provide opportunities for recreation activities involving specific equipment and groups at specific places with given physical-biological, social, and managerial conditions. Managers still are concerned with recreation activities and with the conditions of the recreation setting, but their motivation is to facilitate desired experiences, and thus perceived benefits, for recreationists. In acting on these ideas managers may utilize the ROS and LAC processes, which themselves are based on notions of experience-based management.

Considerable research underlies this approach to management, much of it focusing on users of wilderness and other backcountry areas. We can illustrate some of the background research by focusing on studies done by a Colorado group from 1974 to 1979. Badger's (1975) study of use tolerance levels focused on questions of acceptable levels of interaction among Rawah Wilderness users. For example, what levels of interaction inhibit realization of satisfaction? Harris' (1978) study of crowding and its effect on user satisfaction in the Rawah Wilderness increased our understanding of the relationship between social conditions of the recreational setting and user satisfaction, especially indicating that negative behaviors have a more significant effect on satisfaction than does crowding. Brown and Haas (1980) illustrated that the wilderness clientele in the Rawah Wilderness was quite diverse. At least five different groups, based on experience outcome profiles, were represented in 1975.

A somewhat similar finding was noted by Manfredo and others (1980) in looking at anglers in the Eagles Nest, Rawah, and Weminuche Wildernesses. In general, the same types (based on outcomes) of anglers were observed in the three areas, but nonanglers varied among the areas. Another finding of this study was that both anglers and nonanglers preferred a variety of attributes of the wilderness setting. For example, anglers in the Weminuche placed a higher value on all the physical features of the setting than did either Eagles Nest or Rawah anglers. A series of studies of preferences for attributes of the setting were undertaken in the Boundary Waters Canoe Area, Eagles Nest, Maroon Bells-Snowmass, Rawah, and Weminuche Wildernesses, and Kings Canyon National Park (Allen 1979; Anderson and Brown 1984; Haas 1979; Ross 1980; Zuckert 1980). They identified physical-biological, social, and managerial conditions in these areas that either are important to user satisfaction or cause change in user behavior, thus also indicating an effect on user satisfaction.

Two other significant studies of this group were the experiments by Schomaker (1975) and Krumpe (1979; Krumpe and Brown 1982) to redistribute backcountry use in the Rawah Wilderness and Yellowstone National Park, respectively. Both studies focused on giving recreationists information about the recreational setting that was related to possible experience outcomes. In both cases positive results were found. Schomaker's hypothesis that behavioral intention to follow a particular route and actual behavior would be correlated at a lower level for those groups receiving his information package than for the control group was confirmed. Krumpe, using a decision tree format in his information package, was able to influence the route choice of over 20 percent of the recreationists.

One study was specifically undertaken to test some of the ideas inherent in the experience-based management strategy (Manfredo and others 1983). These authors set out to determine if: (1) there are definable groups of wilderness recreationists that differ on desired experiences, (2) setting preferences differ among recreationists desiring different experiences, and (3) activity participation differs among recreationists desiring different experiences. It was assumed that if these hypotheses were not rejected, the notion from various psychological theories (see Fishbein and Ajzen 1975 and Lawler 1973) that there is a relationship between expected outcomes and behaviors in particular places would be sustained and an empirical basis would exist for experience-based management. The conclusion was "results offer support for the concepts tested; three groups with different preferences for experiences were identified and were found to differ on the activity, setting, and management actions they prefer" (Manfredo and others 1983, p. 263).

No single study confirms the validity of the strategy of experience-based management. All of these studies noted above, plus many others in wilderness and nonwilderness areas, led to the formulation of the experience-based management idea. This idea is not fully operational, but implementation of ROS/WOS and LAC processes, which are consistent with the strategy of experience-based management, will accelerate the process. Then, as we begin to monitor management resulting from the strategy and observe how users behave in response to this management we will be able to evaluate its usefulness and validity.

CARRYING OUT WILDERNESS MANAGEMENT DECISIONS

The broad role of wilderness management, taking a cue from Wagar (1966), is to provide benefits for people. More narrowly we have considered the roles to be maintaining the wilderness resource and providing opportunities for specific uses such as scientific, ecological reserve, and primitive and unconfined forms of recreation. Within the recreation role, we consider the relevant roles to be regulating both the opportunities for recreation and the behaviors of recreationists (Brown 1985).

The major decisions involved in recreation management have been identified as: (1) choosing management objectives, (2) deciding acceptable conditions for each objective, (3) choosing management actions appropriate and effective for reaching the objectives, and (4) changing objectives when evaluation shows a need (Brown 1977a, 1977b, 1985; Brown and others 1976). The first three decisions fit into the process of management planning while the fourth suggests evaluation of actions taken in response to management plans. These decisions describe the role of management in the production of benefits from recreation (Brown 1984; Driver and Brown 1984; Driver and Rosenthal 1982). They suggest that the primary roles for management are producing recreation opportunities and providing information to influence user expectations and behaviors (Brown 1985; Driver and Brown 1978).

Previous sections of this paper summarized research leading to the development of the strategy of experience-based wilderness management. That a number of researchers agree some overall framework or approach must be defined reflects recognition of the complexity as well as importance of management decisions. While individual frameworks vary in how they approach wilderness management, there is increasing recognition that the purposes of management are to identify, maintain, enhance, or restore *acceptable and appropriate conditions* in wilderness settings. By considering the major decisions in recreation management, we can learn what is known about acceptable and appropriate conditions for wilderness and its use.

Management Objectives

The concept of management objectives is prominent in recreation literature. Carrying capacity, Recreation Opportunity Spectrum, Limits of Acceptable Change, and the experience-based management strategies all suggest a need for management objectives. This arises because planning *is* selecting purposes (goals or aims) and choosing means of attaining them (Banfield 1959). Objectives, being measurable and attainable specifications of goals (Young 1970), are specific ways of stating the purposes of management and are thus inherent in any planning process.

Good objectives are time-bounded, and characterized by being specific, output-oriented, quantifiable, and attainable (Schomaker 1984). Objectives are useful in a number of ways. For example, they can help managers determine if a specific technique has been effective in reducing a problem; they narrow the range of acceptable actions; and they provide a specific, attainable target for managers.

Essentially, objectives specify what we want. For example, if the goal is to provide adequate opportunity for primitive and unconfined recreation, the objective will specify what we mean by adequate opportunity. "Adequate" might mean providing 20,000 hectares of primitive and unconfined recreation opportunity; it might be providing 200 persons at one time (PAOT) capacity of this opportunity; or it might involve some other standard of adequacy.

In formulating and choosing management objectives, research information might prove useful. The kind of information obtained from studies such as those by Stankey (1971, 1973) and Brown and Haas (1980) dealing with expectations and desires of users could be important. Such information tells what users think is appropriate for resource and social conditions or for the outcomes to be realized from recreational activity. Research such as that by Helgath (1975) and Cole (1983) is relevant for describing the current condition of the resource so that the manager knows the base from which he is beginning. Studies of use and areas are important for describing baseline conditions, comparisons with other areas, and, when information is available, trends in use.

Acceptable Conditions

Deciding what are acceptable conditions of the resource and recreation engagement occurs essentially during the phases in LAC where indicators are chosen and standards specified (Stankey and others 1985). In the case of providing opportunities for primitive and unconfined recreation, these acceptable conditions further define what we mean by primitive and unconfined recreation. They will describe acceptable limits for resource change, user behavior, and management inputs.

A large amount of wilderness research focuses on questions of acceptable conditions for factors such as encounters between users, appropriate behaviors of users, noise levels, vegetation and soil change, water quality, and user facilities.

The research of Stankey (1971, 1973), Badger (1975), Greenleaf and others (1984), and Shelby and Colvin (1982) is illustrative of kinds of information that are useful for developing standards about interactions among user groups. Stankey, Badger, and Greenleaf and others questioned wilderness and backcountry users about desirable encounter levels at various places in wilderness; Badger

also asked about tolerable levels. Shelby and Colvin asked respondents to indicate the highest number of tolerable encounters for users of the Rogue River. In all cases, users were not anxious to encounter many other groups, and in the case of wilderness areas, excessive encounters at campsites were not tolerable. Generally, Rogue River users had higher tolerance limits than the wilderness users studied.

Noise, as a special factor associated with wilderness use, has had limited study. For example, Dailey and Redman (1975) studied normal background levels and found that noise disturbance depends on intensity, frequency, intermittent reoccurrence, and connotation. For pristine, primitive, and portal situations they provided specific quantitative estimates of acceptable decibel levels so that they could prescribe satisfactory campsite spacing.

Resources have also been the focus of study. For example, Merriam and Smith (1974), Cole (1982), and Leonard and others (1985) have examined vegetation impacts. Helgath (1975), Merriam and Smith (1974), Leonard and Plumley (1979), and Cole (1982) have looked at soil impacts. Barton (1969), Aukerman and Springer (1976), and Werner and others (1985) have looked at water impacts.

A large number of studies have looked at the acceptability of management practices and facilities. For example, Echelberger and Moeller (1977) queried users about the amount and density of trails and the use of patrol rangers in the Cranberry Backcountry and found that both were acceptable. Womble and others (1978) found both toilets and shelters, and Bultena and Taves (1961) found both toilets and fireplaces to be acceptable to the users they questioned.

Lucas' (1985) study recorded changes in preference and attitude of users of Montana's Bob Marshall Wilderness between 1970 and 1982 and thus provided planners with information about how use, users, and attitudes toward development of the wilderness are changing. He found, for example, that support for high-standard trails grew significantly while support for toilets decreased and support for patrol rangers remained the same from 1970 to 1982. Some changes are undoubtedly due to experiences in the Bob Marshall while others are due to changes in clientele. A striking example of the second case deals with interpretive signs. Interpretive signs were opposed by 1970 users while a majority of 1982 users favored them. But in 1982 they still were opposed by experienced users while novices favored them.

Management Tools

Management tools are the means of meeting the conditions specified by management objectives and standards. They are constrained heavily by prior decisions, but nonetheless are influenced by the existing situation, institutional directives, and expectations and desires of wilderness users.

Several authors have described the array of wilderness management tools as being located on a continuum from "light-handed" to "heavy-handed," based on the degree to which they modify versus regulate visitor behavior and freedom (Gilbert and others 1972; Lime 1976; Lime and Stankey 1971; McCool 1976). Peterson and Lime (1979) proposed that management actions can be directed at the consequences of visitor behavior (such as rehabilitation or restoration of campsite conditions), regulating behavior directly (through group size limits, campsite assignments, use limit policies), or through an indirect approach that manipulates the factors influencing visitor decision making (information about use densities, for example). Nearly all authors who have written on this topic agree that in wilderness settings, indirect approaches such as information and education are preferable to direct "heavy-handed" regulatory methods (Hendee and others 1978; Lime 1976; Lime and Stankey 1971; Lucas 1982, 1983; Peterson and Lime 1979) that might result in more intrusions into the experience.

These researchers are supported by vocal outcries by many wilderness users and commentators against direct regulation of visitors. For example, Behan (1974) reacted strongly against the suggestion of mandatory wilderness use permits by Hendee and Lucas (1973) despite the probable usefulness of permits in wilderness management (Fazio and Gilbert 1974). Some authors have even proposed "no rescue" wilderness areas—places where there would be both no regulation on visitor behavior as well as no rescue of users in case of injury (McAvoy and Dustin 1981, 1983). While the merits of this extreme alternative have been debated (Allen 1981; Wagar 1981), the fact that the proposal has been seriously put forth indicates a major concern among users with the potential intrusiveness of wilderness management tools.

Table 2 displays the array of management actions listed by Lime (1976). He listed actions according to their "heavy-handedness." In spite of the substantial discussion of this issue by a variety of researchers and managers, no research to date has identified the degree of "heavy-handedness" of different management actions. Our expectation is that many people will agree about the amount of "heavy-handedness" at the ends of the continuum, but there will be considerable debate about techniques somewhere in the mid-range. This gap is especially cavernous given the numerous debatable statements about wilderness and management (see Wuerthner 1985) as well as the heavy reliance on the construct by researchers (see Lime 1976).

Research focusing on appropriate and effective management tools has been carried out for many years and has focused on three major areas: (1) the acceptability of various management actions; (2) use and effectiveness of information in changing wilderness behavior; and (3) development and discussion of use limit policies. The first item in this list is the subject of review elsewhere in this volume (Stankey and Schreyer), so we will not repeat that information here.

We will focus our attention on the contemporary issues of information and use limit policies for two different reasons. First, information is a technique that many wilderness managers employ. Washburne and Cole's (1983) study of managers indicated that nearly 60 percent use information programs to help minimize impacts, more frequently than any other management tool studied. Martin and Taylor (1981) also reported that managers frequently depend on brochures, maps, and signs to encourage minimum-impact behavior. Second, use limit policies, and

Table 2.—Types of recreation management methods

Method type	Goal	Management tool
Site management (Emphasis on site design, landscaping, and engineering)	Harden site	Install durable surfaces (native, nonnative, synthetic) Irrigate Fertilize Revegetate Convert to more hardy species Thin ground cover and overstory
	Channel use	Erect barriers (rocks, logs, posts, fences, guardrails) Construct paths, roads, trails, walkways, bridges, etc. Landscape (vegetation patterns)
	Develop facilities	Provide access to underused and/or unused areas Provide sanitation facilities Provide overnight accommodations Provide concessionaire facilities (camping, picnicking, boating, docks, and other platforms, playground equipment, etc.) Provide interpretive facilities
Direct regulation of use (Emphasis on regulation of behavior; individual choice restricted; high degree of control)	Increase policy enforcement	Impose fines Increase surveillance of area
	Zone use	Zone incompatible uses spatially (hiker-only zones, prohibit motor use, etc.) Zone uses over time Limit camping in some campsites to 1 night, or some other limit
	Restrict use intensity	Rotate use (open or close roads, access points, trails, campsites, etc.) Require reservations Assign campsites and/or travel routes to each camper group in backcountry Limit usage via access point Limit size of groups, number of horses, vehicles, etc. Limit camping to designated campsites only Limit length of stay in area (max./min.)
	Restrict activities	Restrict building campfires Restrict fishing or hunting
Indirect regulation of use (Emphasis on influencing or modifying behavior; individual retains freedom to choose; control less complete, more variation in use possible)	Alter physical facilities	Improve (or not) access roads, trails Improve (or not) campsites and other concentrated-use areas Improve (or not) fish or wildlife populations (stock, allow to die out, etc.)
	Inform users	Advertise specific attributes of the area Identify the range of recreation opportunities in surrounding area Educate users to basic concepts of ecology Advertise underused areas and general patterns of use
	Set eligibility requirements	Charge constant entrance fee Charge differential fees by trail, zone, season, etc. Require proof of ecological knowledge and recreational activity skills

Source: Lime (1976)

how they are implemented through allocation and rationing programs, are controversial actions, which in many primitive river recreational settings have resulted in lawsuits, political pressure, and civil disobedience (McCool and Ashor 1984; McCool and Utter 1981). While these techniques and associated actions (campsite assignments and permits regulating use) have been implemented in only a few wildernesses, there is considerable concern about them among the using public. They are probably the most "heavy-handed" of the tools managers are likely to employ because they directly regulate behavior by restricting access to scarce resources. While most wilderness managers now agree that such approaches should be avoided if at all possible, there will continue to be situations where use limits are necessary to protect or restore wilderness conditions.

Research on Information.—Information is an increasingly important wilderness management tool. A study conducted in California's Yosemite National Park illustrates the need to understand more about how visitors use information. Bear-human conflicts had been increasing for several years, and improper food storage was the cause of 70 percent of all such incidents in the Yosemite backcountry. The National Park Service embarked on an information program to change backcountry users' food storage techniques to reduce the attractiveness of campsites to bears. Cella and Keay (1979) reported that about 95 percent of the backcountry users received the special brochure on bears, which contained information on proper food storage. Despite the high percentage of visitors who had received bear brochures, and while 92 percent of the campers believed they were properly storing food, checks of actual storage techniques indicated that only 3 percent were using correct methods. These results document the need to understand more about how people obtain, process, interpret, evaluate, and use information in wilderness settings.

While it has been only in the fairly recent past that researchers have turned to examining information as a management tool, there is substantial recognition of its "light-handed" nature. "Information seems to be a highly desirable visitor-management technique. It is nonauthoritarian and can serve the visitors' desires. . ." (Lime and Lucas 1977, p. 21). Most importantly, it alters visitor behavior while preserving freedom of choice.

While understanding how visitors use information developed by wilderness managers is important in selecting media, developing the message and appeals, and designing an information program, it is effectiveness, or how such information influences behavior, that is the ultimate goal of such programs. Effectiveness of various communication techniques is the subject of a tremendous amount of research in American society. Businesses are concerned about the effectiveness of their advertisements, politicians want to know if they are swaying the voters, teachers desire changes in cognitive levels of their students, attorneys are interested in influencing a jury of the guilt or innocence of a defendant, and wilderness managers want to know if their investments in minimum-impact programs are cost effective relative to implementation and enforcement of regulations.

There appear to be two types of behavior changes of interest to wilderness managers. First, management often wants to shift use patterns within a wilderness. The objective may be to reduce the pressure on attractive areas or to lessen the number of encounters in heavily used areas. Second, management also is concerned about changing visitor behavior to forms having fewer impacts on the resource. Research has addressed both issues.

As mentioned earlier, wilderness managers rely heavily on information to reduce or mitigate impacts from recreational use. Yet we know little about what managers are communicating to visitors and how visitors perceive that information. Fazio's (1979) study of wilderness information brochures found that about 16 percent included historical subjects; 30 percent discussed sanitation or fire prevention; 73 percent addressed appropriate wilderness equipment, safety, and comfort; and about 60 percent discussed "wilderness manners." Learning more about the subjects managers communicate about and how they do it is an obvious research need.

What have we learned about the visitor's use and perception of information? Research specifically directed toward this question has been minimal. The studies that have been conducted address several themes: (1) sources of information about alternative wilderness opportunities; (2) use of information to distribute visitors within the area; and (3) use of information to encourage minimum-impact behavior. Because of the lack of cumulative research, the conclusions presented within each of these themes should be considered tentative and in need of additional supporting research.

Research on Information-Seeking Behavior.—

1. *Potential visitors seek out and use a variety of information when making decisions about wilderness recreation opportunities.* McLaughlin and others (1984) and Utter (1979) have shown that friends, relatives, and acquaintances are frequently the most influential sources of information about a recreation opportunity. Dowell and McCool (1983) reported that less than 30 percent of their respondents indicated contact with Forest Service offices prior to a wilderness visit. They also reported that 90 percent of the visitors considered accurate maps desirable forms of information; 71 percent considered guidebooks desirable. Maps were the most frequently cited sources of information used for selecting trailheads.

2. *Visitors prefer an optimal amount of information that is provided outside of wilderness boundaries.* Lime and Lucas (1977) suggested that visitors could be provided with too much information, information that could detract from the exploratory and adventurous character of wilderness opportunities. This point of view is reflected on occasion by wilderness visitors seeking places that are simply "blank spots on the map." Dowell and McCool (1983) reinforced this statement when they found that only 37 percent of the visitors desired explanatory signs within the wilderness, implying that off-site information is more acceptable than information within the wilderness. An exception is the finding of Lucas (1982) that indicated that a majority of present users of the Bob Marshall Wilderness in Montana favored interpretive signing.

Research on Use of Information To Distribute Visitors.—

1. *Information can be effective in distributing visitors within an area.* Early in the history of recreation research, Brown and Hunt (1969) demonstrated that information, in their case highway signs, could be effective in changing use patterns from one area to another. This result was confirmed by a study of canoeists in the Boundary Waters Canoe Area (Lime and Lucas 1977) and of backcountry hikers (Echelberger and others 1983). Lucas (1981) attempted to shift use patterns from heavily used trails to more lightly used ones through a brochure made available at the trailhead. The brochure showed the relative amount of use among several adjacent trails and drainages. His study did not demonstrate a significant effect in redistributing use. A similar study by Schomaker (1975) yielded the same results. He found that behavioral intentions were influenced by a message about crowding and use in the Rawah Wilderness, but that his message,

given at the trailhead, came too late for much change in behavior on the current trip.

This study was followed by a classic field experiment (Krumpe and Brown 1982) in Wyoming's Yellowstone National Park. As backcountry visitors entered a ranger station to secure their permit, they were randomly selected to receive either a treatment (a backcountry "trail selector" map) or no treatment at all. Over 20 percent of the visitors changed their planned travel route when given alternatives supplied through the selector. A similar study reported by Roggenbuck and Berrier (1981) showed that campers in a North Carolina wilderness changed from heavily used to lightly used travel and camping areas in response to information about alternative campsites.

The results of these studies have enhanced our understanding of the conditions that make use dispersal information effective as well as when this technique does not seem to work.

2. *To be effective, information on alternative trails and locations must reach the recreationists at an appropriate point in the decision making process.* The Lucas (1981) and Schomaker (1975) studies showed that information about alternative trails presented at the trailhead was too late. The Krumpe and Brown (1982) research was conducted at ranger stations; many backcountry visitors still were in a position to change their minds about which trail to hike. Similarly, at the trailhead, Roggenbuck and Berrier (1981) informed visitors about alternative campsites well before the final campsite was selected. The brochure used by Lime and Lucas (1977) was sent to potential visitors prior to the summer use season, when initial decisions were being formulated.

3. *To be effective, information on alternative trails and locations must include descriptions of a variety of characteristics.* Krumpe and Brown (1982) and Lime and Lucas (1977) credit part of the success of their work to the variety of information made available to visitors. Lucas (1981) felt that focusing information on use levels alone was inadequate, a point recently reinforced by his (1985) finding that Bob Marshall Wilderness visitors more frequently mention scenery than solitude as a reason for entering the wilderness, and that encounters with others do not necessarily impact satisfaction.

4. *Use of information varies by experience level and degree of specialization.* Recent research suggests that more-experienced visitors use information differently than less-experienced visitors (Huffman and Williams 1986). Generally, it appears that experienced visitors rely less on agency information and more on personal communication and previous experience in making decisions about travel routes. Williams and Huffman (1986) reported that specialized hikers used information to the same extent as nonspecialists, but they tended to seek more detail in the information they received.

Research on Use of Information To Encourage Minimum-Impact Behavior.—

1. *Increases in knowledge about recreation impacts are accompanied by changes in attitudes and behavior.* A variety of research has examined the effectiveness of differing treatments in environmental education efforts (Schwabb 1982-83; Weiss and Knudson 1980; Zimmerman and others 1978). These studies show that use of information in situations similar to wilderness settings can result in major shifts in knowledge levels and subsequent behavior.

Only recently have researchers begun examining the effectiveness of minimum-impact information programs. Robertson (1981) demonstrated that among the nine independent variables (age, gender, occupation, income, primitive camping experience, conservation group membership, education, attitude toward wilderness, and knowledge of recommended wilderness behavior) she studied, knowledge was the most important contributor to minimum-impact behavior. This suggests that if knowledge levels can be changed, impacts can be reduced.

Oye (1984) examined the effectiveness of a wilderness education program in bringing about cognitive as well as affective changes in sixth-grade students. Knowledge scores were significantly increased (as compared to a control group), but attitudes remained the same.

Dowell and McCool (1986) reported the effectiveness of three alternative modes (slide program, booklets, slides and booklets) of presenting a Forest Service-developed program to Boy Scouts, heavy users of wilderness resources in many regions. Cognitive levels and behavioral intentions for the three treatment groups were higher than for the control. Among the independent variables studied (wilderness skills knowledge, general wilderness knowledge, beliefs and attitudes), wilderness skills knowledge was correlated the highest with behavioral intentions.

2. *A variety of methods can be used to communicate minimum-impact behavior skills.* The Dowell and McCool (1986) study used three different modes (slides, booklet with discussion, combination of slides and booklet) of presenting the program using both a highly credible source (male Forest Service uniformed employee) and a source of presumed lower credibility (nonuniformed female). Unlike some other studies (see Fazio and Gilbert 1974), this study showed few differences among the treatments, essentially indicating that the form in which information is presented makes little difference. No differences attributed to source credibility were found either.

Oliver and others (1985) measured actual behavior in a developed campground following a variety of information treatments regarding minimum-impact behavior. While their study showed some variation among treatments, all were statistically effective.

This line of research tends to confirm the validity of the managers' reliance on information as a tool that can be used to address impact problems. Offsite, managers must contend with retention issues; onsite, managers may have to compete with alternative attention grabbers (users may not visit an area to learn minimim-impact behaviors). However, we need to know more about information and education programs, their design, application, and effectiveness. Lucas and others (1985, p. 185) stated:

> ...more needs to be done to identify the *key information* that we supply to visitors, *how* to best convey this information, how to determine whether education *produces* the desired behavior, and finally, how to *evaluate* the performance of different educational approaches as well as other management strategies.

Use Limit Policies.—While carrying capacity was the strategy around which much research and management were oriented in the 1970's, many managers sought to implement this construct through use limit policies. As noted earlier, a fundamental problem with the way in which carrying capacity was popularly defined was its emphasis on numbers of people, rather than on the appropriate and acceptable conditions for wilderness settings. "How many is too many?" was the question that managers posed and that researchers tried to answer.

Consequently, a number of areas, principally primitive river recreation settings, established use limit policies in the 1970's (Utter 1979). Research in river settings was directed not only at understanding the needs and motives of visitors, but also at how they perceived the acceptability and necessity of use limit policies and how those policies were implemented through allocation and rationing techniques. Often, limiting use in river situations was also complicated by Western water law, definitions of navigability, the public rights doctrine, and political posturing by various interest groups (Simmons 1977; Utter 1979).

Initial definitions of the extent and complexity of the unresolved and perplexing issues associated with use limits were provided by Warren (1977) and Stankey (1977). It quickly became apparent that this was a management problem without precedent. Not only were legal doctrines involved, but fundamental constitutional rights and responsibilities frequently became the center of litigation. These types of problems anchored one end of the spectrum, while at the other end managers dealt with such basic questions as the design of the form for a permit, type of rationing system desired, deadlines, "duplicate" reservation requests, and campsite assignments. The complexity, level of detail, and legal-philosophical issues soon became an overwhelming quagmire for management. The problems were especially acute on whitewater rivers in western North America where managers had been quick to adopt some type of use limit policy (Schreyer 1977).

A number of researchers turned their attention to these questions. Stankey and Baden (1977) and Shelby and Danley (1979) identified a range of alternative rationing approaches as well as the conceptual issues involved in dealing with rationing and the various consequences of different techniques. Investigations concerning the acceptability of limiting use were reported by Stankey (1973, 1979, 1980), Lucas (1980, 1985), and Shelby and others (1982) in designated wilderness. A number of researchers, including Schreyer and others (1976), Schreyer and Nielson (1978), Utter (1979), and McLaughlin and others (1984), addressed the issue in primitive river recreation settings. This research has led to a number of conclusions about use limit policies and how they are implemented.

1. *Visitors accept a use limit policy if there is agreement that such a policy is necessary to protect wilderness conditions.* One of the consistent results researchers have found is that in a wide variety of settings visitors will accept a use limit policy. Generally, however, such acceptance is contingent on a clearly defined need to protect either the wilderness resource or the experience. Stankey and Schreyer (this volume) review the research on visitor acceptance in greater detail.

2. *Wilderness visitors generally prefer reservation and queueing rationing systems, while river floaters prefer lotteries.* Generally, wilderness users were found to be more reluctant to accept lotteries (Shelby and others 1982) as a rationing technique than river recreationists (McCool and Utter 1982). Pricing was unanimously found to be unacceptable. Reservations (Schomaker and Leatherberry 1983) and first-come-first-served systems were usually favored over other alternatives. One technique that several have advocated, rationing by merit, did not find much favor. Stankey (1972) and Schreyer and others (1976) found that perceptions of the acceptability of differing rationing techniques are often influenced by the motives for visiting the area.

3. *Implementing use limit policies is a complex process that requires clearly stated objectives concerning how use is to be allocated.* Establishing a use limit policy is only the first step in a tremendously complicated process (McCool and Utter 1981). Following its implementation, a number of decisions are forced on the manager, including the potential of allocating use between outfitted and nonoutfitted users (Buist 1981). Such details of implementing use limit policies have been addressed by several researchers. Shelby and Danley (1979) argued for explicit statement of the specific goal of an allocation system: equity, equality, efficiency, or need. Shelby (1981) presented the economic values involved in allocations to river outfitters. Cordell (1981) suggested that some system similar to the free market be permitted to reduce use levels. McCool and Utter (1981) presented a framework for decision making following implementation of a use limit policy. Shechter and Lucas (1978) developed a wilderness travel simulation model that would help managers identify the consequences of alternative use management policies.

It now appears that a use limit policy is a technique of last resort. As managers have gained experience, there appears to be a general dissatisfaction with the technique as a way of solving problems even though many of the day-to-day operating problems have been smoothed out. Use limit policies are derived ultimately from the "how many is too many?" perspective. Managers and researchers now understand that for a use limit policy to be effective in solving problems there must be a unique and unambiguous relationship between use level and impact (Shelby and Heberlein 1984). In complex, two-dimensional spaces covering large and varied terrain, such a relationship may be difficult to uncover or establish.

We have learned much from our research and experiments with use limit policies. First, these policies probably generate more complex problems than they solve, particularly in the way they are implemented. While there is support among the using public for limiting use if necessary to protect or restore wilderness conditions, there is less agreement about how to implement the policy. Second, the policy itself is not an effective management response to specific problems of impact, crowding, or conflict. If it is implemented it must be complemented by additional tools. Third, there is growing recognition, indeed even preference (Wuerthner 1985), for other approaches to solving the problem because these other approaches have fewer side effects.

Much of the research in this area has depended on preference data from wilderness visitors. However, it would seem desirable to expand and build on this foundation through simulation experiments. Simulations can help subjects more realistically identify and react to the consequences of alternative use limit policies and how they are implemented. Simulations also can help managers understand how a particular policy will work, who will be affected and how, and the costs involved in implementation.

Monitoring and Evaluation

The final major class of management decisions focuses on how well the prior decisions about management objectives, standards, and tools meet social goals for wilderness management. We ask, "How effective and relevant is the management system?"

Research evaluating implementation of standards, management tools, and wilderness plans is scarce, though some of the research cited above does help both in making decisions about selecting appropriate tools and in changing the management program in response to evaluation. Stankey and others (1983, 1985) discussed monitoring and evaluation in recreation and wilderness and Lee's work (1982; Lee and others 1983) in the Steens Mountain Area of Oregon gave user evaluation of standards used in designating various backcountry recreation zones. A note by Leonard and others (1980) gave guidelines for monitoring use of backcountry trails. Papers by Anderson (1977), Echelberger and others (1981), Marnell (1977), and others suggest how to count recreation users. Our conclusion regarding monitoring and evaluation research is that there is a lot that needs investigating. Use of processes such as those associated with the ROS, LAC, and experience-based management will help provide the grist for both good evaluation and research on evaluation needs and processes.

Wilderness research has been done with an eye toward each of these major management decisions—choosing objectives, selecting indicators and standards, choosing management tools, and evaluating and changing the management system when necessary. What has been done is by no means exhaustive, and we can learn considerably more about wilderness, its use, and its management.

FUTURE RESEARCH: IMPROVING THE EFFECTIVENESS OF WILDERNESS MANAGEMENT

As noted earlier, our knowledge concerning how wilderness visitors feel about management and their motives, expectations, and characteristics has increased considerably in the last 20 years. We have an enhanced appreciation of the relationships between types and levels of recreational uses, impacts on the resource, and the wilderness experience. We now have far greater understanding of concepts important to wilderness experiences, such as solitude. We are beginning to see how attributes of wilderness settings affect visitors and their experiences. The fact that nine lengthy state-of-knowledge papers (this volume) can be written on different dimensions of wilderness-related research indicates that a fundamental knowledge base has been established.

In response to issues of crowding, conflict, and impact, managers have developed a large array of potential management techniques. Wilderness research has helped in this task because of its applied orientation and through the relationships that have developed between many wilderness researchers and managers. These relationships strongly enhance the ability of managers to communicate information needs and lead to researchers producing results useful to managers.

Researchers, themselves, have developed a set of management tools and concepts. Researchers, responding to managers' problems of identifying a carrying capacity, developed the LAC and the design capacity notions. Researchers also developed the wilderness travel simulation model. We expect the wilderness research community to continue to play this important role. While not research in the sense of "experiments" and statistical analyses, these contributions are important to technology development, transfer, and application. Their contributions, and the effectiveness of their use, rely on continued close relationships between management and research.

Our knowledge concerning the usefulness of new management concepts is limited, however, by the inability to evaluate them following application. For example, the efforts to learn under what conditions campsites in wilderness are impacted, the amount of the impact, the biophysical elements impacted, and the rate of impact have produced the opportunity for managers to deal more effectively with this problem. This knowledge serves as a base for managers to develop techniques to reduce impacts. However, we really know very little about these management techniques in terms of their effectiveness in reducing the problem. When managers develop techniques to reduce impacts based on results from research, they are actually performing "experiments," but often because of funding problems, or simply because managers are not trained in experimental design, or are unaware of the principles of monitoring (Stankey and others 1983), the actual effect of these experiments may not be known. Research can help overcome problems of lack of followthrough or objective measurement.

Testing the Effectiveness of Various Management Techniques

Ideally, this type of research would follow accepted experimental design and sampling principles. The research reported by Oliver and others (1985) demonstrated how experimental design can enhance our understanding of the effectiveness of different management techniques. While this type of research will cost money (as all research does), it has distinct payoffs in terms of learning what techniques are effective and under what conditions. Likewise, we are likely to determine why certain techniques are not effective. The manager could then allocate seemingly ever-scarcer dollars to techniques that are effective in maintaining or restoring acceptable wilderness conditions.

We must be careful about conducting this research. Because of its "opportunistic" nature, there will be a tendency to avoid theoretical constructs, a criticism that has

been levied at wilderness visitor research before (Lee 1977). As researchers, we have a responsibility to ensure that our efforts are cumulative. Brown and others (1973) warned about the "Recreation Research, So What?" paradigm. We suggest that some type of research program be outlined to provide for greater opportunity for cumulative, synergistic contributions.

This type of research also will require close cooperation between managers and researchers, and may require managers to assume some risk to assess unproved techniques. To some extent, this will require researchers to take a risk also, because a certain amount of this research may not be the type that leads to tenure and promotion decisions.

But what type of management techniques should be the subject of research? There has been no systematic nationwide problem analysis of wilderness management research needs to provide guidance in making recommendations. Washburne and Cole (1983) did provide some insights into what managers perceive to be problems, but they did not ask managers to identify either research or information needs. Thus, in addition to the need noted above, the following are our impressions of what needs to be done.

Investigate the Legitimacy of Information and Education Tools

We hope that researchers soon will begin looking more closely at education and information as specific management techniques. We suggest this because of the frequency with which managers depend on them (Washburne and Cole 1983) and because of the lack of attention they have received in the wilderness research literature. Several questions need to be addressed. First, are such techniques effective? Do they result in changes in visitor behavior, specifically with respect to minimizing per-person impacts? What techniques are most effective for a specific problem? For example, are slides or personal messages more effective? Do different groups require the message to be presented differently? How does a manager educate those groups that may be responsible for much of the impact but which are also difficult to reach through standard channels of communication? What factors affect the transfer of knowledge in this situation? Is there a monitoring system for measuring effectiveness that could be used by field-level managers on a periodic basis?

We suspect that addressing this issue is going to require much in the way of interdisciplinary design and cooperation. Ecologists will have to identify the nature of the problem and supply the "correct" behavior. Media specialists will need to translate this information into an appropriate message. We can learn much from education research in terms of message design and delivery. Social-psychology can tell us something about how people will use this information, the situational and social factors affecting internalization of it, and the relationships between such factors as media, source credibility, message content, and changes in cognitive levels and behavioral intentions. Some of this research and experimentation may actually be done in a laboratory, while other components will require field experimentation. All of it should be done within theoretical constructs that will tie the fragmented studies together.

Identify How to Manage Ecological Impacts of Recreation in Wilderness Settings

Another line of inquiry concerns managing biophysical impacts in wilderness settings. Cole's review (this volume) shows that we know much about the relationship between types and levels of use and impacts. Again, however, the effectiveness of managing those impacts is an issue that must be addressed if impacts indeed will be reduced. For example, Ranz (1979) found that closures of campsites to reduce impacts in one part of the Selway-Bitterroot were ignored by a large proportion of the visiting public, and eventually led to the development of new campsites, thereby increasing the area impacted while only modest ecological recovery was observed on the closed campsites. Two questions are suggested by this research. First, why did many visitors ignore the obviously signed closures? Second, are recovery rates fast enough to justify closures if additional campsites (impacted areas) are created? Again, the research will have to be interdisciplinary and done in different geographical areas to be effective.

A similar question deals with trail conditions. Lucas (1985) reported that trail conditions were a main problem perceived by visitors to the Bob Marshall Wilderness complex in 1982. Is this a concern in this area alone? A large proportion of the money available for wilderness management is spent on trail construction, relocation, and maintenance. Thus, research may provide many benefits by allowing this money to be spent more efficiently. Research questions may focus on relationships between use types and levels and amount of impact. Management actions may be limited; it seems that educating visitors about trail impacts may have little effect, except perhaps in reducing the frequency of shortcutting switchbacks and in changing travel methods to less impacting ones. Research, for example, could focus on identifying soil types resistant to trail uses and researchers could assist managers in applying remote sensing technology to trail location and design. Also, levels of site management and engineering acceptable in wilderness need to be determined.

Investigate the Appropriate Roles of Various Wilderness Management Tools

A major unanswered question, one that has not had any research, is the construct of a "light-handed - heavy-handed" continuum underlying the array of management actions. As we noted earlier, a number of authors have postulated that this construct does describe the continuum, but there has been no verification of this. Several questions need to be examined. First, do visitors perceive such a continuum? Second, where do different techniques lie on it? Third, what are the roles of the techniques identified along this continuum? Several assumptions have been made that regulations are heavy-handed, but is this how the visitor perceives regulation? Frost (1985), for example, has shown that in some situations visitors may perceive regulations as enhancing experiences, not detracting from them. Under what kinds of conditions does this occur? A fourth issue deals with the tradeoffs among different types of regulations and the benefits and costs to the experience. For example, limiting use in a wilderness may be

perceived by visitors as beneficial if there are no regulations once they enter the area. Thus, the location of a technique on the continuum may shift. Under what conditions do such shifts occur?

Define the Wilderness Management Job and the Skills Needed to Competently Carry Out the Associated Duties

Wilderness management is a relatively new field. What does the job involve? What types of skills are required to be an effective and competent wilderness manager? Why are some managers more likely to adopt the results of research than others? Here we expect the "diffusion of innovation" literature from rural sociology to be helpful. Why are certain management concepts and techniques more likely to be adopted than others? For example, many wildernesses now have a natural fire management policy. However, the backcountry trail selector developed by Krumpe and Brown (1982) (which demonstrated effectiveness in dispersing users) has not been adopted by any managers. Why was one adopted but not the other?

Given the fundamental changes in our society that are now occurring (see Toffler 1980), research could help identify the implications for managers. We fear that because of the traditional values involved in wilderness preservation, some managers may be caught in a conflict between these values and the new technology available to help get the job done efficiently. The changes occurring in social structure and values may be difficult for some to adopt. For example, Toffler indicated that the public wants to be more involved in governmental decision making. Research can help by identifying new ways for the public to participate (Ashor 1985; McCool and Ashor 1984; Stokes 1984) and new ways for managers to use the input they provide.

Evaluate the Consequences of Use Dispersal Policies

We feel there is a great need to specifically research the consequences of "use dispersal" policies. On many occasions, we have been told the answer to impact, crowding, and conflict problems is to disperse use. Cole's findings (this volume) suggest that such a policy may have severe negative consequences for the biophysical setting in sensitive Western areas while Leonard and others' (1985) findings suggest dispersal might be good in areas of the East. We hypothesize that a use dispersal policy also may reduce opportunities for solitude in those regions of a wilderness presently receiving light use. Perhaps the present users of these regions seek them because of the opportunities for solitude. Dispersing use into these areas could thus reduce the solitude available. Because of the frequency with which this management technique is suggested, we feel that research needs to look at it carefully before irretrievable commitments are made. Tools such as simulation models (Shechter and Lucas 1978) can help researchers and managers in this task.

Evaluate Existing Management Systems and Frameworks and Facilitate Creation of New Systems When Necessary

Finally, we need to learn more about entire management systems and regimes. LAC has become popular among some managers, but it has been implemented in only one or two situations as of this writing. We need to examine the success of LAC in these situations, the obstacles presented, how they were overcome, how specific problems were identified and dealt with, and if LAC eventually did make a difference on the ground. This is an important and high-priority line of inquiry because LAC might become more frequently used in management planning for wilderness. A major part of LAC is its requirement for monitoring. Monitoring can be used to determine the effectiveness of the overall process as well as individual management techniques, and results of the monitoring need to be diffused through the wilderness management field so that the level of success or failure with the system can be established.

Evaluation of a management regime will be a difficult task, and it may require a panel of researchers and managers working together. We feel this is necessary because without formal evaluation, we may not know if the regime has been successful. The causes of the success or failure will need to be identified to improve the regime and to notify other managers of what to seek and what to avoid. Also, in evaluating what we are doing, we likely will discover other things that might be done and begin to create better management processes. Such discovery, however, will surely be advanced if the evaluation is done with a clear idea of what management is designed to do.

Clearly we have learned a great deal about wilderness management, but considerably more remains to be learned. Research and management together have only begun to learn about user behavior, resource impacts, and the effectiveness of managing to ensure an enduring wilderness and opportunities for high-quality primitive and unconfined forms of recreation. A challenge for the future will be to be as productive as we have been in the past 25 years in learning about managing wilderness and its users.

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Section 4. Future Directions

ENVIRONMENTAL PROTECTION AND PRESERVATION RESEARCH PRIORITIES

A. Alan Hill

It is indeed a pleasure to join with you today. I've looked forward to being with you since Glenn Haas visited me early last spring and outlined the important purposes of this conference.

I'm sure that if we polled this room we could come up with as many statements of the value of wilderness as there are people attending. One of my favorite thoughts about wilderness came from a cab driver in Washington, DC, a couple of weeks ago. This gentleman told me he knew all about wilderness because he's had a flat tire in Rock Creek Park!

Now I'll claim a little greater wilderness exposure than the man driving the cab. The point of my story, though, is that each individual values some kind of wilderness experience for his or her own personal set of reasons.

When I was a Scoutmaster, we took a trip to Oregon's Three Sisters to earn the "50 Miler" patch. I remember on a particularly trying day when one of the Scouts, who was concerned about protection of the area where we were camping, told me he remembered what Theodore Roosevelt said, "Walk softly and carry a big bed!"

During our family trips to wilderness areas in the Sierra, my boys learned to fish. My wife and I have developed an interest in wildflowers. And, most important, we've learned respect for the rare visit to camp by a representative of the Ursidae family.

Over this time, which spans nearly 25 years, we have seen the passage of the Wilderness Act and participated in discussions of the size, boundary, inclusions, and exclusions of many of the formally designated wildernesses. More accurately, we have seen the establishment and growth of the National Wilderness Preservation System, a system of preserves that now contains nearly 90 million acres. Let me underline the word "preservation."

President Reagan put it best last year when he said, "Generations hence, parents will take their children to these woods to show them how the land must have looked to the first Pilgrims and pioneers."

THE VITAL QUESTIONS

Now, the nation has had more than 20 years experience, and it is most important to focus on the vital questions for the years ahead. Those relate to issues of protection and management of these vital resources. It is quite appropriate for researchers to gather to compare findings and to communicate with all interested parties, including the people who carry out management programs.

I'd like to take the next few minutes to share some of the thoughts we at the Council on Environmental Quality have regarding wilderness—that is, on wilderness in the broader perspective of the national good, not merely the personal benefit we derive.

Last fall and winter, CEQ convened a set of four 2-day meetings of experts to focus on the need for long-term environmental research and development. We issued our final report on March 18, 1985. Basically, the panels focused on specific research areas. Those are:

- human health impacts and their mitigation;
- geochemical and hydrologic processes and their protection;
- environmental impacts and their mitigation; and finally,
- monitoring, assessment, and environmental management.

Our project was a cooperative effort of EPA, the National Science Foundation, the Department of Energy, the National Institute of Environmental Health Sciences, and the Nuclear Regulatory Commission. Copies of the report are available through CEQ.

While many of the recommendations go to issues well beyond those concerned with wilderness, there are many which will bear directly on the subject of this conference.

One underlying theme of this conference is "information"—information developed through research monitoring and the contribution and maintenance of accurate data bases. I am reminded of a story that appeared in the **Chicago Tribune**:

> Abraham Lincoln was vastly disturbed during the Civil War because he was so often denounced and criticized by people who pretended to be wise on a minimum diet of facts and information. They offered wisdom they did not possess. So, whimsically he told the story of a backwoods traveler lost in a terrific thunderstorm. The rider floundered thru the mud until his horse gave out. Then he stood alone in the middle of the road while lightning streaked and thunder roared around him. One crash seemed to shake the earth underneath, and it brought the traveler to his knees. He was not a praying man but he made a petition short and to the point: "O Lord, if it is all the same to you, give us a little more light and a little less noise."

The point is, we cannot give light or wisdom we do not have, and we do more damage than good when we speak with authority from a vacuum of knowledge and information.

LONG-TERM LOOK NEEDED

In order to remove that vacuum, we need to begin at the beginning—and that is with research—research which spans as great an amount of time and covers as many critical areas of concern to be useful and effective. We need to look at the long term.

Long-term environmental research and development (R&D) includes three kinds of activities: (1) anticipatory research, designed to identify potential environmental problems before they occur; (2) investigations of a continuing nature, such as ecological baseline studies, which may require a period of up to several decades to complete; and (3) fundamental research, the output of which may advance basic understanding of environment-related processes.

Scientists knowledgeable about health and environment recognize that human pressures placed upon natural resources, both living and nonliving, are more severe than previously suspected.

During the past 40 years a wide variety of new synthetic chemicals has been introduced, some of which appear to pose serious acute and chronic health effects. Of similar concern is evidence of potential damage to such important natural processes or properties as biogeochemical cycling or biologic diversity.

Ignorance about many scientific questions has resulted in acknowledged problems of environmental management, such as inappropriate regulation in the face of data uncertainties or heightened public anxieties. Long-term environmental and health research is needed to resolve scientific uncertainties, to establish baseline health and environmental parameters, to overcome lack of understanding of the short-term variations in natural systems, and to identify long-term trends and relate them to their causes.

For a variety of reasons, current incentives for private sector and governmental support of environmental and health R&D favor short-term approaches. Government agency research programs are generally designed to support mission goals of the agencies sponsoring them, resulting in relatively short-term research planning horizons that do not extend beyond immediate regulatory or programmatic requirements. Similarly, corporate research efforts frequently support near-term product development strategies and are necessarily reflective of annual (or shorter) profit and loss statements.

Current government and public concern over such environmental problems as acid deposition phenomena illustrates the fallacy in continued reliance on short-term research design. Although the potential environmental and health effects of acid particulates were pointed out years ago, relatively little research attention was devoted to following up on early studies noting these effects, and commitment of resources could not be justified on the basis of then-current regulatory strategies. Accordingly, long-term acid rain research programs were deferred; had they been undertaken a decade ago, they might by now have been yielding information and predictive models of use to current regulators and policymakers.

We believe there is need for a greater resource commitment to and better direction, coordination, and interdisciplinary integration of long-term environmental and health R&D. Improvements in environmental management will flow from better characterization of environmental phenomena, increased understanding of basic mechanisms, and the development of more meaningful measures of hazard or harm assessment. There clearly is a need for good long-term monitoring data and accompanying quality assurance to evaluate models used for understanding processes and environmental trends. Lack of validated monitoring time series data, based upon even crude health and environmental measures, has impeded the expansion of fundamental research programs.

In addition, modeling can be an integrating force for the environmental research community, in that the imposition of modeling requirements yields helpful insights in identifying needs and opportunities for new research. However, the use of models must be accompanied by continuing efforts to validate them.

Only with research continuing over many years, and for projects that extend over a substantial period of time and that are focused on fundamental issues, will the Nation be able to develop the credible and necessary expertise to better rationalize environmental management policies. Environmental science needs a critical mass of talent and resources to effectively approach the challenge of understanding complex environmental and health phenomena.

MONITORING AND ANALYSIS

One of the recommendations made by the panelists is of primary concern to you. It concerns data monitoring, collection, and analysis.

Monitoring yields essential current and time series information on the status of environmental systems, information used both for environmental management and for regulatory compliance. The panelists believed that the lack of coordinated scientific procedures accounts for such problems as nonstandardization of monitoring practices and failure to monitor for parameters of greatest importance or relevance.

In spite of significant efforts expended on the collection of environmental data by a variety of unrelated and uncoordinated State and Federal agencies, no adequate system exists for the integrated collection, storage, maintenance, and quality control of such data. It was recommended that CEQ foster an evaluation by an appropriate organization of existing physical, chemical, and biological monitoring programs (and extant data associated with them) to identify and stimulate research and development on improving the quality and cost effectiveness of monitoring programs. Particular emphasis should be placed on determining requirements for

biological and environmental monitoring, on identifying pollutants such as toxic chemicals for sampling, and on determining information and statistical requirements for environmental models.

In this regard, the Council has addressed the idea of an Interagency Initiative on Environmental Monitoring and Data. There are several compelling reasons to revisit the environmental monitoring issue from a comprehensive, multiagency perspective. You are all concerned with the collection and sharing of data and the need for better ways to accomplish your given tasks. Recent studies point to the continued need for improvement in the monitoring of environmental trends, and in the more effective dissemination of information on environmental quality to all concerned organizations and individuals.

In addition, there is clear Congressional interest within the last 2 years pointing to the need for resolution of monitoring problems, and proposing a national environmental monitoring commission to do what the agencies themselves could be doing. The increasing budgetary austerity that most agencies will face argues for the use of common methods, cooperation in monitoring common parameters, standardization of methods, and the pooling of data.

CEQ AS CATALYST

Because of its location within the Executive Office of the President and the Council's responsibilities relative to environmental information, CEQ can effectively serve as the catalyst to encourage multiagency cooperation in this area. What we propose is the following:

> To establish a core group within the Council on Environmental Quality and an oversight committee composed of representatives from Federal agencies to undertake such tasks as:
>
> 1. Update and publish a report on Environmental Trends in the Nation.
> 2. Identify an aggregate set of key environmental indicators capable of assessing the environmental health of the nation.
> 3. For each indicator proposed, recommend an approach for collecting and aggregating data, under which measurements can be obtained regularly and cost effectively.

You in this room today well realize that comprehensive environmental management approaches depend upon the availability of reliable theories, data, and expert opinion. Advances in environmental sensors, information processing, transfer of scientific and technical knowledge, and use of environmental data bases can increase our ability to effectively manage our environment.

SOME BASIC QUESTIONS

Basic scientific research, and monitoring and assessment activities, provide useful but voluminous amounts of information that must be evaluated to assure its reliability in identifying, resolving, or mitigating environmental problems. However, in identifying long-term research and development needs, it is important to first distinguish between research and monitoring; that is, between studies that attempt to improve our understanding of how environmental systems work, and studies that provide data on the status of those systems. Our basic understanding must guide the choice of what parameters to monitor, and questions of research priorities and quality control must be answered.

In order to improve methods of data analysis and interpretation, a number of additional questions must be answered. For example, how are the large environmental data sets currently maintained by the Federal regulatory and management agencies being used? Are they used in state-of-the-art models and analyses that are clearly related to human health and environmental quality and which reflect our knowledge of how systems work? Are they ever used to improve our basic understanding of how systems work? How many people outside the agencies use the data? What are the problems and impediments in using and interpreting the data? Has basic knowledge about the working of the systems being sampled been used to increase the efficiency of sampling and the utility of the data in detecting trends?

Through your efforts in the development of environmental information resources, you can help evaluate the cost effectiveness of previously implemented programs, while identifying where additional efforts are needed, thereby determining where funds need to be allocated. You are able to assist in the promotion of new programs by substantiating the effectiveness of other similar programs and to justify budget requests for these programs.

Proper management of our wilderness system supplies researchers with living laboratories to provide vital base line data. Wilderness thus is offering our Nation more than recreation opportunities alone. Wilderness is a vital part of the national interest in environmental quality. I want to commend you for your interest and good work. Please accept my sincere good wishes for the future.

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INTRODUCTION TO WILDERNESS RESEARCH NEEDS PANEL DISCUSSION

William A. Worf

To this point in the conference we've reviewed wilderness research findings and perspectives after more than 20 years of living with the 1964 Wilderness Act—a kind of "state-of-the-art" review. It is extremely important that we stop occasionally and take stock of where we are and how we got here. But the greatest value of such an assessment is to establish a base from which to plan and launch future programs. This morning we have a distinguished panel representing wilderness users and administrators. The panel's charge is to tell the conference from their perspective what issues/problems/opportunities are confronting wilderness managers which the scientific community can help to resolve.

There are several precepts that managers and researchers alike must keep clearly in view as we struggle to maintain an enduring wilderness resource for this and future generations. Before introducing the first speaker, I'll briefly review five of these.

LEGISLATIVE BASIS NECESSARY

First: Everything we do in both management and research must be firmly based on the Wilderness Act and its legislative history. Speakers in this conference have repeatedly reminded us that the term "wilderness" has different meanings to different people. Harold Eidsvik told us that other nations have difficulty understanding the concept. That is not surprising because the concept is uniquely American—it flows from our pioneer heritage.

While a number of our philosophers and naturalists have written extensively about wilderness, the concept embodied in the U.S. National Wilderness Preservation System doesn't come from any one of them. The concept isn't Henry David Thoreau's, Aldo Leopold's, John Muir's, Art Carhart's, or Bob Marshall's. It contains elements from the philosophies of all of these men—and those of other people. It is a composite of ideas and compromises forged in the heat of Congressional debate for 8 years.

There are very few of us that would not like to change some aspect or provision of the Act to make it conform more closely with our personal idea of what wilderness should be. However, if managers and researchers allow these personal biases to guide management decisions or influence research designs, our wilderness system will soon be only a "grand experiment" that failed. Each manager's personal bias would take every wilderness in a different direction. Each of us has an obligation to future generations to make the whole idea work as designed in the Act.

WILDERNESS IS FOREVER

Second: Wilderness is forever.

Rod Nash told us yesterday we should not justify the establishment and maintenance of wilderness simply for the future. I agree. It is important for us here and now. Nevertheless, we are charged by the Wilderness Act to maintain an enduring resource of wilderness for this and future generations. Our greatgrandchilderen—or theirs—may have no interest in wilderness as defined in the Act, but we must provide them with the option.

We need to be constantly aware that even seemingly small impacts of shortsighted management rationalizations and precedents could have cumulative effects that will destroy the system gradually over the years. Conversely, courageous decisions like the one recently made by Forest Service Chief Max Peterson will gradually strengthen the system. Max refused to allow EPA to take the "easy way" and use helicopters on wilderness lakes to complete the Western Water Survey. There is no question about the importance of that study to determine the effects of acid rain, but Max said it could be done without resorting to helicopter use. He said if EPA people didn't have the ability or commitment to get the job done the wilderness way Forest Service people did. Forest Service people will collect the samples using foot or horse travel methods. Hundreds of similar potential impacts confront the wilderness system each year.

ONLY ONE PIECE

Third: Wilderness is only one piece of the conservation picture.

Those of us who love the wilderness may sometimes get so engrossed in the battles of designation and management we forget that its very existence depends on how well we manage those lands outside of wilderness. To maintain areas where primitive recreation and outstanding opportunities for solitude will always be available we must provide adequate opportunities for those who want to enjoy the outdoors from the seat of a trail cycle, snowmobile, or automobile. To keep some areas where forests will live, die, and regenerate themselves in a truly natural way we must provide elsewhere for the sustained yield of timber, forage for livestock, or managed habitats for wildlife and fish.

Wilderness can furnish knowledge that will help mankind feed, clothe, and shelter itself. We as wilderness supporters must see that this knowledge is put to use, and we must take positive steps to ensure that lands

managed for the production of other resources are managed to produce a sustainable flow of those resources.

ONLY ONE VALUE

Fourth: Recreation is only one of the values of wilderness.

When I first became involved in the management of the Bridger Wilderness some 24 years ago I viewed it as a recreation area—a somewhat esoteric one to be sure—but a recreation area nonetheless. Subsequent study and work has impressed on me the fact that while the majority of those using wildernesses directly are recreating, recreation is not the most important long-term value of wilderness. Preoccupation with recreation has led to the suggestion by some people that equipment, structures, installations, or activities that are generally prohibited will have little or no adverse impact on wilderness if current recreation users don't object or if the activity can be hidden from them. They would say a set of camouflaged instruments, a power saw outside the heavy recreation season, or the landing of a helicopter in winter are really OK. Hiding such activities or things will reduce the impact on current recreationists. It will not, however, prevent the cumulative erosion of the wilderness character of the land.

Just as wildernesses are not recreation areas, neither are they elk ranges, research areas, or scenic areas. The wilderness resource must take priority in resolving all conflict to the extent not prohibited by the Act's special provisions. This determination by managers that the wilderness resource is dominant has led to concern by some scientists, as expressed in this conference by Jerry Franklin and others. They say that research activities are being discriminated against. Some scientists have pointed to the scientific purpose listed in the Wilderness Act and asked permission to conduct research that involves the use of aircraft, structures, instrument installations, or some form of vegetative manipulation. They have often been unhappy when their requests are denied. The Act makes it clear that the gathering of information about resources is authorized but it must be "carried on in a manner compatible with the preservation of the wilderness environment" [Sec. 4.(d)(2)].

MUST BE GUARDIANS

Fifth: Wilderness managers must be GUARDIANS not GARDENERS.

This was an admonishment often given to administrators by Howard Zahniser, Executive Director of the Wilderness Society, during the long Congressional debate over the Wilderness Act. Man has a driving urge to improve or fix things. Over the past 21 years I've listened to many urgent and sincere pleas from managers who want to use their management skills to "improve" vegetative diversity, esthetics, or wildlife habitat in wilderness. Others want to give Mother Nature a helping hand to fix something that our predecessors may have fouled up.

The vast majority of these proposals for manipulation by man would only further confuse and obscure the natural processes. They would damage the wilderness resource, not fix it.

If we are guided by these precepts we will maintain an enduring resource of wilderness.

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WILDLIFE RESEARCH NEEDS IN WILDERNESS AREAS

Lynn A. Greenwalt

Having been involved with the management of designated wildernesses since the very first ones were established, I have always harbored a concern which is related directly to the question at hand.

That concern, stated simply, has to do with how wilderness should be managed so as to serve the purpose and intent of the Wilderness Act. Should wilderness be managed, in the literal sense of that term, in order to maintain the kinds of wildlife and habitat relatively typical of those areas in their pristine state, or should it be left alone to evolve in accordance with the influence of natural processes as they are presently constituted?

DISTORTION POSSIBLE

Obviously, very large wildernesses are more nearly subject to the functioning of natural processes that are not dissimilar in their impact to what would have occurred in times before European man began to exert his considerable influence. However, even these larger areas are affected by human inclination to control wildfires and to introduce pervasive and possibly significant pollutants into the air (acid rain), and they also are influenced by cattle grazing, timber harvest, and various kinds and degrees of recreational use. Smaller areas are even more profoundly affected, of course, to the extent that the effects of fire, grazing by wild animals (bison), and other processes that made them dynamic are at least interrupted or may be foreclosed altogether. The result may be a distortion of the ecosystem—at least in terms of what we might expect, based upon what these areas were known to be like in former times—even to the point where they may be perfectly "natural" but hardly representative of wilderness in an historic sense.

The question is perhaps more one of philosophy than an identification of research needs, but it occurs to me that it might be fruitful to contemplate research to determine what it is people expect from their newly created wilderness heritage (including what they prefer to pass along to their successors). An obvious consequence of knowing this, of course, will be a need for research to determine how to make this happen, including an identification of the ways these lands should be managed (including manipulation) in order to realize the expectations of those for whom wilderness areas have been set aside.

A question derived from all this—or which should be addressed apart from the somewhat more cosmic concern outlined above—has to do with how fish and wildlife species have fared in established wildernesses. It might be unusually revealing to compare data from wildernesses to information obtained from the same or similar areas prior to wilderness designation. This should be done with selected nongame as well as game species, though game species are likely to be the ones the welfare and status of which are foremost in the minds of many wilderness users.

A PROVOCATIVE QUESTION

Finally, and provocatively, there is the kind of question which arises from the fact that the responsibilities for the management of resources in wildernesses are more often than not split between the State wildlife agency and the Federal land-management organization. This is a dichotomy of long standing, carefully crafted to recognize the fact that States have the right to manage the wildlife (including fish) and the Federal land managers have the responsibility to manage the habitat.

With wilderness designation there is a change in the way the land manager must approach his responsibility, based upon the idea of limiting human intrusion, controlling the nature of activities permitted, and a requirement that the lands so designated be managed in keeping with the tenets of the Wilderness Act. This may or may not pose a problem in that State agencies through which the wildlife are managed do not have the same restraints (if they are indeed restraints).

There may be a need to identify whether any major problems have arisen in wildernesses as between the goals of the State wildlife agencies and the goals of the land management organizations involved. There have, to be sure, been some at least brief conflicts concerning such matters as the use of aircraft to stock fish in remote areas in units of the National Wilderness Preservation System.

ARE CHANGES NEEDED?

It may be useful to determine whether there are many such problems, and if so, if they are widespread and of moment enough to pose problems now or in the future. Are they subject to resolution through presently available processes, or are regulatory (or statutory) changes needed?

These may be problems of small concern now, but it would be well to give them continuing and proper attention, since it would be tragic to have serious conflicts arise, perhaps to erode unnecessarily the aspirations and purpose envisioned for the Nation's system of wildernesses.

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QUESTIONS FOR FURTHER WILDERNESS RESEARCH

Robert E. Howard

The Sierra Club is a 350,000-member organization whose purposes are to explore, enjoy, and protect the wild places of the world. Since 1892, the Sierra Club has worked to preserve parks and wilderness. It is a "grass-roots" organization of concerned, active citizens. Many of them are wilderness users as well as wilderness protectors.

From the Sierra Club's viewpoint, the following are particularly important issues and questions for further wilderness research:

1. Emphasis on protection of wild ecosystem information. This includes information contained in the gene pool, in unperturbed natural processes, and in wilderness characteristics. One of the most pressing areas is study of the quality, characteristics, and conditions of air, water, and soil in wilderness as a baseline for the effects of air, water, and toxic substances pollution.

2. Study the morbidity of wilderness flora and fauna due to pollution, as opposed to their mortality. The concept of wellness or healthiness of each component of the ecosystem suggests that research should concern factors causing morbidity, not just mortality. Especially focus on factors causing chronic, long-term morbidity, and the subtle interactions of such morbidity in ecosystem cycles and processes.

3. Determine exactly what occurs across wilderness boundaries as interfaces. What are the transboundary relationships and impacts of nonwilderness activities (sights, sounds, smells, pollution, movement of biota) on wilderness, and vice versa? Determine what potential management tools exist to address transboundary impacts.

4. Increase the study of desert and fragile mountain wilderness ecosystems. This is particularly important with the forthcoming Bureau of Land Management wilderness designations. There are related needs regarding international de facto wilderness areas.

5. Develop a means to assess the relative needs and values of managing the wilderness resource itself versus managing human users and usage of wilderness. There are various perceived needs and values in the management of fire, wildlife, biotic succession, pests, soil erosion, and water resources. Similarly, there are perceived needs and values in the management of recreational, research, grazing, mining, and other direct users of wilderness, and in indirect usage of wilderness for water resources, as an airshed, as a potential neutralizer of toxic substances in groundwater, etc.

6. Research methods of more effectively informing, affecting attitudes, and modifying behavior of users. Applied social psychological research directed toward identifying those methods amenable to development as management tools is needed. Although the first applications would presumably be to direct wilderness users, the same or similar methods would probably be useful with the general public.

7. Determine a priori what "immediate benefits" to wilderness would result from exception to the restrictions on motorized access in wilderness. The Wilderness Act requires immediate benefits to wilderness as the criterion for granting exceptions to the restrictions on motorized access in wilderness. Managers should have a clear notion of what benefits might result from a proposed exception. They should also have a clear set of guidelines to determine whether the benefits reasonably and probably would result. An example of the problem is the use of helicopters for acid rain research in wilderness.

8. Determine what mineral, oil, and gas leases are outstanding in wilderness. A database of current and accurate information would be useful to many. Related subquestions include: Under what conditions were leases issued? How many leases were grandfathered? How many were erroneously issued? How many are still valid? What is the cumulative impact of these leases?

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PITFALLS IN WILDERNESS MANAGEMENT—LET'S AVOID THEM!

Clifton R. Merritt

Wilderness management and research have indeed come a long way in the two decades since the Wilderness Act was passed. Four days of this exceptional National Wilderness Research Conference have made this fact clear.

This alone vindicates those hardy pioneers back in the 1950's who said, "We need a national wilderness system under law." For, until the enactment of the Wilderness Bill in 1964, wilderness, like beauty, was in the eyes of the beholder. Even longtime wilderness buffs had widely differing views as to what wilderness was and how it should be managed.

But enactment of the 1964 landmark legislation changed that situation. The Act defined wilderness legally and spelled out how it was to be managed. Henceforth, wilderness was what the law said it was, and it was to be managed as the law provided. There was less room for uncertainty and subjectivity.

The law strengthened and gave direction to management and allowed research to move ahead. Both have prospered.

PITFALLS IN PROSPERITY

But in their prosperity there are pitfalls that both wilderness managers and researchers must avoid if wilderness is to survive.

They must recognize and accept the fact that wilderness areas are **not** primarily recreation areas. Recreation is not the only use of wilderness. The 1964 Wilderness Act specifically states that, "Except as otherwise provided in this Act, wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use."

Since the law does not mention priorities, each of these public purposes or uses is equal in importance under the law. They must be given equal consideration by management.

More than a few public land managers have been giving primary attention to the recreational aspect of wilderness. It is easy to do this. The recreational use is more visible, political. This is the anthropocentric approach. If it prevails, it will ultimately destroy wilderness.

The anthropocentric approach deals to a large extent with managing wilderness for man's use. It concerns itself with such matters as how the visitor **feels** about wilderness and its management. Thus, it can lend itself easily to too much subjectivity. Take, for example, the matter of whether a bridge should be built across a stream in the wilderness. Perhaps crossing the stream without a bridge presents some risk. But wilderness users to date have gotten by without it. And isn't all wilderness use at some risk? Where do you draw the line before you have so many bridges, hardened trails, and semideveloped campsites that the area may be a convenient recreation area but no longer wilderness? Let's face it. While wilderness management and research have come a long way since passage of the parent Wilderness Act, they still have a longer way to go in educating and continuing to educate the user public about wilderness. Conservation organizations have a major responsibility here, too.

Far too many users view wilderness as just recreation areas. And they have a wide range of thoughts as to how the areas should be managed. For them, consideration of the other public purposes of wilderness is in its infancy—or hasn't been born yet. Left on their own, many of them would tear up and trash up the wilderness—or love it to death. They need to be told much more about these other purposes of wilderness. They need to learn more about the biocentric approach to wilderness management, which focuses more on the biological and other physical resources of the wilderness.

Obviously, managers and researchers must employ a proper mix of both anthropocentric and biocentric approaches.

NATURE MUST PREVAIL

The bottom line in wilderness management is preserving the wilderness character. Man can always create a recreation area. But once destroyed, the primeval scene can never be restored. Wilderness management is largely managing the people who use the wilderness, so as to preserve its wilderness character. In wilderness, the forces of nature must prevail.

Another major consideration that I feel has not been adequately addressed at this conference is that wilderness is not an island unto itself. It does not exist in a vacuum. Moreover, it cannot continue to exist if the people responsible for managing and researching it do not look beyond its borders. We must avoid this pitfall.

Jim Posewitz, environmental director for the Montana Department of Fish, Wildlife and Parks, in an address last winter before the annual conference of the Montana Wilderness Association, said it best. He spoke of limits of acceptable change, as applied to the 1.5 million-acre Bob Marshall Wilderness complex in western Montana.

Said Posewitz, in part:

> Overuse of quality recreation opportunities or quality recreation areas is without a doubt a serious problem. We must be careful, however, not to focus solely on the wilderness as a solution. At issue here is not dividing the remnants of wilderness among the myriad of competing users or individuals seeking that wildness. Overuse of the wilderness will not be solved by restricting its users. It must be achieved by halting the taming of all nonwilderness remnants, by reclaiming substantial blocks of our increasingly battered forests, and by initiating a user education process.
>
> Wilderness is freedom. You can't ration, computerize, or regulate freedom. It's a contradiction in concept. We must all resist the debate over how we will limit ourselves and our use of the Bob Marshall Wilderness complex. The problem is really that, for some types of recreation, the Bob Marshall is all that's left. The solution to use problems in the Bob Marshall may lie in addressing what is happening to the rest of the public lands.
>
> If pressure must be relieved, then let us reclaim the Little Belt Mountains to the extent that we can once again have an early (and long) elk season. The same for the Bitterroots, the Big Belts, and other pieces of overcompromised wild country.
>
> The future of hunting, the future of fishing—the future of wildland recreation—does not lie in rationing the classified wilderness. The future of all these activities lies in the careful husbandry of all public lands and doing what is necessary for the reclamation of those lands that have been compromised excessively for the production of commodities alone.

To manage a wilderness area best for all its public purposes, then, we must understand how it is being affected by management of the nonwilderness public lands that surround it, and what we must do to eliminate or minimize the outside adverse impacts to the wilderness resource itself.

INVOLVEMENT NEEDED

Finally, managers and researchers can manage and research wilderness until the end of time, but if they don't involve in their work the people who use the wilderness, they will have but little to show for their efforts. For this reason, I would like to have seen many more leaders of environmental groups attend this conference. Many of their people use wilderness. By acquainting the leaders with wilderness management problems and research implications, and by obtaining their enthusiastic involvement in solving these problems, you will have advanced a hundredfold the noble work in which you are engaged.

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INSTITUTIONAL RESEARCH FOR A DEMOCRATIC WILDERNESS POLICY

Bernard Shanks

We are things forgotten when the ice withdrew,
and meant to perish really,
but the ice forgot, and somehow from the ice-streams
we survived
—a tough ill-mannered beast, out thinking all the rest.
There's just one thing: whatever made us never taught
how to out think ourselves.

From "Why Does the Cold So Haunt Us?"
—Loren Eiseley (Eiseley 1977)

The most troublesome issues and problems confronting wilderness lands are also the most difficult for traditional researchers. It is easier, for several reasons, to cast the net of science over manageable fry like the user, entrepreneur, wildlife, or other resource or experience. Nevertheless, it is appropriate to consider the fundamental problems which threaten wilderness—political processes, and managers, public land, and educational institutions. The questions in this arena are many and essential:

- How in our democratic society does wilderness conservation compete with private economic activities?
- How does society craft the institutional structure for public land management which adequately serves the public and future generations?
- How are land managers trained to serve the public interests rather than the private commercial sector?
- What is the role of our universities in wilderness education and research?

The problems of wilderness management and protection are ingrained in the very fabric and structure of public land management institutions. Until we address the structural problems with research meaningful in a political-policy environment we will fail to have a truly democratic system of land management. These problems go beyond the usual philosophical conflicts of protection vs. development. They concern whether we will have a public trust system of land management or a system by management elites for economic elites.

When public land products are viewed in an economic framework we find the land management agencies are subsidizing virtually every commercial activity on the public domain. In the political arena we find a rise not in a public trust but a rationalization of private greed—first in the guise of the "Sagebrush Rebellion," more recently in the form of "privatization" theory. The institutions which once implemented a major revolution in American society, conservation, now are unwilling or unable to refute fashionable political or economic trends.

DRAMATIC CONTRASTS

Today's specialization of public land managers, educators, and researchers has taken the subject of public land policy far afield from its historic principles. Yet the writings of Teddy Roosevelt and the pioneers of our profession rested on a solid ethical foundation. When have we seen or heard the ethics of public land management discussed by our leaders today?

Roosevelt, in dedicating a new entrance to Yellowstone, could say, "I cannot too often repeat that the essential feature in the present management of the Yellowstone Park, as in all similar places, is its essential democracy—it is the preservation of the scenery, of the forest, of the wilderness life and the wilderness game for the people as a whole, instead of leaving the enjoyment thereof to be confined to the very rich who can control private reserves" (Roosevelt 1926).

The contrast with today's management of public lands is dramatic. Frequently we see a handful of individuals, sometimes one person, directing public land management and wilderness policy. Today, the Federal land agencies devote most of their energy—staff time, resources, and money—the very things we measure in public policy analysis—to the subsidization of private economic activities on public lands.

The program failures of the agencies have been more specific than a drift into a welfare role. Despite a clear policy mandate the land management agencies have largely failed to prevent continued erosion and degradation in the quality of public lands. The agencies have failed to provide efficient management based on the least costs and maximum public benefits. We have a failure to develop meaningful partnerships with States and local government, or to prevent wasteful interagency conflicts. Even a seemingly simple program like the consolidation of public lands becomes hopelessly bogged down. Finally, the agencies have failed to respond to national publics and changing environmental values.

Wilderness as a public policy has been and still is opposed by the very institutions that are charged with the management of wildland. The result is a shortage in the supply of wilderness. The agencies provide indifferent, if not hostile, wilderness management. Overall there is a lack of resources, including research, directed toward one of the most democratic forms of land conservation.

Pinchot wrote in his autobiography, "Everyone knew that neither money or political influence could dictate to the Forest Service . . ." (Pinchot 1947). Today, the activities of the Forest Service are largely concerned with

money—economic activities on the National Forests—and no one could deny the special interest political influence over the management of public forest lands. The land ethic of early conservationists like Roosevelt and early foresters like Aldo Leopold does not fit the fashion of today's political climate.

PROBLEM CORE

How did our agencies fail the public trust? What has been the role of the "professional" in land management? A recent **Journal of Forestry** article gives some indication of the role of chauvinism and management elites in public land management: "Many foresters see this second campaign (against preservation) as the defense of the profession's very underpinnings." The article goes on to lament the "rising tide of preservation" and calls politics the greatest obstacle of all to professional forestry (Heinrichs 1985). To me this paternalistic, elitist attitude of foresters and range managers has been the core of wilderness conservation problems. It advocates a technocratic approach to a public trust subject. The phenomenon seems an appropriate subject of wilderness research.

- What has been the cause of the land management bias against wilderness?
- Why has the public trust in public lands been largely lost in today's policy discussions?
- Are today's professionals lacking in the foundation of history, philosophy, and ethics which the early leaders held at the core of their work?
- How does a profession, a group of land managers, working on public lands, set itself above the democratic process and develop hostility toward the political process?
- Why have the land management professions, at one time at the forefront of a great political and social movement, now become the last to accept changing values and attitudes toward land, endangered species, preservation, and wilderness?
- What role have our universities played in this process?

We need research on these tough, but fundamental, questions rather than the easy ones regarding the social-economic characteristics of wilderness users.

More importantly, we need research on how we can train and prepare public land managers with a professional orientation toward what Roosevelt termed the "public as whole."

Finally, what institutional structure do we need for the long-term management and protection of wilderness? It seems increasingly obvious that the multiple-use agencies have failed to respond to the national public needs in the area of wilderness conservation.

- Do we need a new agency to protect and manage wilderness?
- How would we develop the framework for such an organization and how should it be staffed and supported?
- If that approach is not feasible how do you change relic managers and aging institutions?
- How are social changes and democratic processes incorporated into public agencies?
- How does the public gain control of public trust lands and for the next several generations assure that the management will not be dominated by special economic interests?

REFORM REQUIRED

Undoubtedly, educational reform is required for national resource programs. The narrow, highly specialized vocational training must give way to broader education. Emphasis should be on communication, ecology, and the ethics and philosopy of quality land management. Most important, public land managers should have a clear understanding of the democratic process, with its flaws, that is the political process.

Research emphasis should be broad and holistic. Policy research, which measures results and efficiency, should not be buried in dusty archives. Instead, the results must be directed toward the key leverage points in the policy process and launched into the public arena for debate and discussion.

Undoubtedly, these questions are not likely to be researched by the agencies themselves nor the landgrant universities that conduct most wilderness research. It is easier and more politically comfortable to research the smaller, more manageable questions. Such questions will have to be addressed, most likely, by the private nonprofit conservation community or the new Wilderness Research Foundation.

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WILDERNESS ISSUES AND PROBLEMS THE SCIENTIFIC COMMUNITY CAN HELP RESOLVE

Steven Child

The Aspen Wilderness Workshop is conducting a baseline monitoring project in the Maroon Bells/Snowmass Wilderness located in west-central Colorado. The project is being done in cooperation with the Aspen District of the Forest Service, U.S. Department of Agriculture.

The Maroon Bells/Snowmass Wilderness is probably the second most heavily used wilderness in Colorado, after the Indian Peaks Wilderness, which is located near the Front Range urban area. Parts of the Maroon Bells/Snowmass Wilderness are very overused, and the Forest Service is searching for a method of trying to reverse the trend.

This baseline research project is designed to measure several parameters that can be checked annually or semiannually. The information collected will be used to determine if the condition of the wilderness is improving or deteriorating, and will help the Forest Service determine what management steps need to be taken in an individual section of the wilderness.

The four areas being studied include: campsite condition, trail condition, vulnerability of lakes to acid precipitation, and user response to the social condition (how many people are using the wilderness and do the users perceive it as being too crowded or overused).

MAROON BELLS/SNOWMASS PROBLEMS

Problems presently occurring in the Maroon Bells/ Snowmass Wilderness include:

1. Too many people in popular areas around lakes and hot springs has led to degradation of campsites through soil compaction, loss of vegetation, lack of firewood, and sanitation problems including *Giardia* contamination in the water.

2. Loss of wilderness-type experiences and lack of solitude.

3. Pressure on wildlife species (you see essentially no big game species in the overcrowded areas).

4. Conflicts between livestock grazers and hikers due mostly to overgrazing along creek bottoms where the hiking trails also tend to be. The Forest Service has responded in some instances by closing areas to grazing, and in others by shifting to better grazing management techniques.

5. Severe erosion on trails leading to popular climbing routes. These trails often go straight up very steep hillsides.

6. Threat of a deterioration of air quality due mainly to development upwind of nearby oil shale facilities. Other wildernesses in the State are being impacted by coal-fired power plants.

7. Conflicts caused by outfitter use, including permanent camps in some areas, and trail erosion from too many horses.

8. Potential problems due to the introduction of llamas to the Colorado high country. What are the long-range implications of introducing a South American animal into our Country?

OTHER WILDERNESS PROBLEMS

Problems occurring in other Colorado wildernesses include:

1. Pine beetle infestations. This problem tends to be self-limiting in high-elevation areas where most present wildernesses are located. What efforts, if any, should be made to control it?

2. Water diversion projects, especially in the Holy Cross Wilderness and the proposed Williams Fork Wilderness. The answer to this problem may lie in the development of water-saving measures and technology in the Front Range urban areas that are proposing to divert the water.

3. Damage caused by mountain bikes on trails in nonwilderness lands.

4. Mining.

MAJOR ISSUES

1. Should the Maroon Bells continue to be a sacrifice area to help keep too many people from going to less-used areas, or should efforts be made to direct people to less-used wildernesses or nonwilderness areas to spread the impact out?

2. What heroic measures should be taken to try to minimize the impact of man in wilderness, such as hardening the trails with gravel, or building safe bridges?

3. At what point should wilderness managers begin limiting the numbers of people going into an area to protect the resource? Random questionnaires handed out in the Maroon Bells/Snowmass Wilderness indicate that most people do not feel it is too crowded, even when numbers of trail encounters and campsites occupied indicate that capacities are already exceeded.

4. Should a permit system be started? What parameters should wilderness managers be using in determining when an area becomes too crowded? There is a need for baseline data and methods of developing easily quantifiable measurements which would be useful to wilderness managers.

SOLUTIONS AND OPPORTUNITIES

1. The solutions to some of the problems lie in areas outside the regular realm of wilderness management. For example, the development of water-saving technology could lessen or eliminate the need for a major water diversion project in the Holy Cross Wilderness in Colorado. Air pollution control regulations and technology applied outside wilderness (like in the oil shale area or copper smelting areas) would help lessen air pollution inside wilderness. Development of new camping gear such as camping stoves can help preserve campsites and trails.

2. Can space-age technology help in managing wilderness? An example of this would be to determine the extent of the impact of man through the use of satellite photographs.

3. There is a need for baseline studies to be done now in many wilderness areas to determine the extent and type of wilderness use, the condition of trails and campsites, the condition of wildlife populations, and air and water quality, especially to determine the extent of acid precipitation damage.

4. There is a need to find more accurate ways to quantify damage to vegetation by acid rain. We shouldn't study just lakes, but should study the forests before they start dying.

5. We need to develop better techniques for polling wilderness users, and educating them.

6. We need to determine the long-term effects on the backcountry of mountain bike and llama use.

7. We need to develop a Wilderness User's Pill to lessen the urge of people to go to the wilderness, and to make them more aware of and sensitive to their surroundings when they do.

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NEW CHALLENGES FOR WILDERNESS RESEARCH

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Most of you have heard the phrase "the new kid on the block" used when referring to the Bureau of Land Management and our managing of wilderness areas on the public lands. This phrase is certainly appropriate when applied to our new wilderness responsibilities. But it is just as appropriate when considering our wilderness management research needs. As it is with the kid in a new neighborhood, BLM is also going to confront its fair share of new challenges when managing wilderness, and will have to rely on its well-established "neighbors" to help adjust and meet these challenges for achieving the basic goals of wilderness management.

Compared to the responsibilities of the other three Federal agencies managing wilderness, BLM's 369,000 acres of wilderness in 23 separate units, ranging in size from a 5-acre island on the Oregon Coast to the 110,000-acre Paria Canyon/Vermilion Cliffs Wilderness in Arizona, hardly seems worth discussion. This will not always be the case. Out of the 25 million acres now under study by the BLM, the potential exists that 8 to 10 million of those acres will eventually be designated wilderness. This still seems small when compared to a wilderness system today of 88 million acres. But the BLM wilderness system does already, and will to a greater degree in the future, contain a tremendous diversity of ecosystems, resource values, and management challenges. Let me mention some topics on which we need research.

Arid-type Ecosystems.—Many of BLM's wildernesses will be located in arid and semiarid regions of the Country. These fragile ecosystems recover slowly from impacts and will require specialized management. Also, BLM wildernesses will be relatively small in size and will contain only fragments of larger ecosystems, creating tremendous outside pressures and potential impacts. We also look to research to help in finding the best ways of reclaiming disturbed desert ecosystems.

Concentrated Public Use.—This can be a big problem, especially in the canyon country. BLM has a lot of canyons under study, and some have already been designated as wilderness—Aravaipa and the Paria in Arizona, and Bear Trap Canyon in Montana. These steep, narrow canyons tend to concentrate and funnel visitors, placing most of the pressures on small portions of the resource. Also, the arid nature of BLM lands tends to concentrate use where water is available. Many of these water sources can sustain little impact. Wildlife is dependent on the same sources; and, in many instances, archaeological sites are also located here.

Ill-defined Boundaries.—We know where they are, but the public may not, because they are not always tied to distinct landforms. This can lead to trespass by offroad vehicles and miners. Are there better ways to handle this problem, short of going all out with signs and fences? We look to research for help.

Recreation Use Is Not the Major Impact.—Emphasis on management, and ultimately the research emphasis, for many BLM wildernesses will not follow the same direction as found in today's wilderness system where managing recreation use is the primary focus. Our needs will be slightly different. Recreation use may not be the major force affecting the wilderness resource. Many BLM wildernesses will be remote, isolated, away from population centers, and will see few recreationists.

Fire Is a Major Management Concern.—For example, some wildernesses in Nevada, eastern Oregon, and southwestern Idaho will have a greater impact and management concern from fire. To make sound wilderness fire management decisions that follow the Bureau's policy of allowing fire to play a more natural role in wilderness, we need to know more about fire histories, the effect of various fire suppression methods on wilderness ecosystems, fire management techniques (such as prescribed burning), and the effects of fire on wildlife, the social/human conditions, and air quality.

Grazing Management.—Another major research need BLM will be confronted with is in managing the nonconforming uses allowed by the Wilderness Act, especially grazing. Many BLM areas now under study for wilderness contain grazing activities, and these activities will continue after the area becomes wilderness. Research can help us in determining compatible grazing levels, the amount of livestock forage to allocate in various types of ecosystems, and how these affect the wilderness resource and recreation use values of an area. Considerable research to date has been carried out on questions related to livestock grazing and the effects of grazing on various ecosystems. What we need is further information specific to BLM wildernesses and ecosystem types, and the overall effect of grazing on different wilderness characteristics.

Collection of Basic Resource and Visitor Use Data.—Most public land areas entering the wilderness system lack basic information necessary for managers to make intelligent decisions. Development of wilderness management plans for each wilderness is a top priority for BLM. Without a reliable data base, sound management decisions cannot be made nor can we be sure objectives

laid out in management plans are being achieved. Research can also assist in establishing Limits of Acceptable Change (LAC) and in identifying the indicators and standards for setting these limits.

Applicability of Past Research.—Past research on wilderness user behavior, recreation use and impact, and visitor management will be partially useful to BLM because we will have similar problems on the public lands. But some of it may not apply in BLM wilderness because of the types of ecosystems and resource conditions, different impacts, or differences in visitor behavior. Researchers may need to reevaluate these findings and determine their applicability on BLM lands.

Unfamiliarity With the "Minimum Tool" Standard.—BLM field managers are unfamiliar with the "minimum tool" standard. Everybody thinks a pickup truck or helicopter is the minimum tool for their activity. We are already receiving numerous requests to continue paleontological studies, wildlife transplants, and archaeological research. And each requestor feels they should be allowed to conduct their activities as they were prior to wilderness designation. What can research do to help us manage these requests?

Communication and Education.—Because of the types of problems discussed previously, and the limited budget for BLM wilderness management, providing information and education to the public and our managers becomes extremely important. We need to know the most effective methods of communication—those which most effectively change visitor action. The research focus on the use of education as a wilderness visitor management technique to be carried out over the next 5 years at the Forest Service's Intermountain Research Station will be most useful to the BLM.

One last research need for BLM concerns coordination, cooperation, and technology transfer. We need to continue to improve in each of these areas. An agency as small as BLM, with extremely limited wilderness management dollars and the potential wilderness management responsibilities we will have, is going to continue to depend upon other agencies, universities, user groups, and the scientific community to develop the knowledge and suggested solutions necessary to help us properly manage wilderness on the public lands. This can only be achieved through good coordination and cooperation and by being aware of new technologies in the field.

To sum up, we want your help in focusing on the research needs of BLM wildernesses. Challenges await the wilderness manager as well as the researcher.

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MANAGING THE WILDERNESS RESOURCE WITH KNOWLEDGE: IMPORTANT WILDERNESS MANAGEMENT ISSUES NEEDING RESEARCH

Ed Bloedel

When choosing research topics, both managers and researchers must take their direction from the Wilderness Act. Here are four important Wilderness Act directions, five major management issues with research needs, and two challenges to managers and researchers.

WILDERNESS ACT DIRECTIONS

1. Allow natural processes to operate freely. We must provide areas "...where the earth and its community of life are untrammeled by man ...." [2(c)]
2. Provide "... outstanding opportunities for solitude or a primitive and unconfined type of recreation." [2(c)]
3. Preserve the wilderness character of the areas. In every management action we take or everything we allow in wilderness it is our responsibility to preserve the wilderness character of the area. As the law states "... each agency ... shall be responsible for preserving the wilderness character of the areas ..." while administering the area for "... public purposes of recreational, scenic, scientific, educational, conservation, and historical use." [4(b)]
4. Manage for special exceptions provided for in the Act and subsequent acts "... as also to preserve its wilderness character." [4(b)]

WILDERNESS MANAGEMENT ISSUES

1. Effectively developing a true wilderness philosophy and ethic in managers, visitors, and researchers (this will go a long way toward solving most of the other issues listed here today). Research needs:

- Identify and develop effective educational techniques and identify target audiences.
- Develop methods to promote desirable human behavior in wilderness.
- Strengthen content of educational material.
- Develop methods to gather information about users and resources without permanent equipment or motorized use.

2. Protecting natural processes (keep "untrammeled") in the face of increasing human pressures and demands to alter the processes for special purposes (certain recreational activities, huntable game species, cloud seeding). Research needs:

- Understanding basic ecosystem processes and interactions.
- Describing plant succession.
- Describing animal species and natural population cycles.
- Describing the natural role of major ecosystem disturbances such as fire, storms, and insect and disease attacks.
- Describing ecosystems not well studied in the Southwest, Southeast, Northeast, and Alaska.
- Understanding the extent of human influence on natural processes including pollution originating outside wilderness.
- Describing the effects of management actions on ecosystems. This is particularly important as we need to develop more "sensitive management systems." For example, present insect control research has led to destructive insect control projects and methods. More work could be done to develop an insect control method that is more "sensitive" to maintaining wilderness character.
- Developing effective monitoring techniques.
- Developing more effective indirect methods of changing visitor behavior to prevent overuse. We need more "light-handed" visitor management techniques.

3. Maintaining "outstanding opportunities for solitude" in the face of increasing pressure for exceptions for special purposes (gathering information with motorized equipment, running horse or human endurance races, doing wilderness management jobs with motorized equipment). Research needs:

- Identify solitude tolerance limits.
- Identify when approved motorized use (Alaska Law) becomes too much.
- Develop methods to manage without motorized equipment.

4. Protecting wilderness from outside pollution sources and from presently "uncontrollable" uses such as low overflights. Research needs:

- Develop methods to control the "uncontrollable."
- Develop effective monitoring techniques that in themselves also preserve wilderness character.

5. Preserving wilderness character while managing special exceptions provided for in the wilderness and subsequent acts. This topic has not been adequately discussed in the wilderness research symposium. Research needs:

- Develop less impactive mineral/oil and gas exploration methods and techniques and improved restoration methods.
- Develop grazing systems that protect wilderness values.
- Develop effective educational techniques to teach ranchers and miners wilderness values.
- Develop effective educational techniques to teach wilderness visitors about the Wilderness Act's provisions for grazing and mining.

CHALLENGES

Here are two challenges I offer the research community. You need to develop with wilderness managers truly interdisciplinary wilderness research projects that start from the premise of protecting the wilderness resource first, then integrate all the other biological and social components of wilderness in a manner that preserves the wilderness resource. All research to date and presentations in this symposium have centered around individual components of the wilderness resource and have been accomplished by single disciplines. This single-discipline emphasis tends to place too much importance on managing one aspect of the wilderness resource that may conflict with another. An example might be recreation use versus a threatened or endangered species. Managers also must improve the involvement of the various disciplines necessary to do a better job of wilderness management.

Before I state my second challenge, I wish to lay to rest the myth that the Forest Service discourages research in wilderness. The Forest Service strongly supports research in wilderness that is done ". . . in a manner compatible with the preservation of the wilderness environment." [4(d)(2)] To protect the wilderness environment by keeping it "untrammeled" and providing "outstanding opportunities for solitude," we discourage the use of motorized equipment and the installation of instruments. For the same reasons and to keep wilderness from becoming overcrowded, we discourage research in wilderness that is not dependent on a wilderness environment.

My second challenge is: why is it so hard for the researcher (or the manager for that manner) to accept this "sensitivity" to the protection of the wilderness character while gathering data? Are we so hung up on "modern technology" that we cannot keep it out or hold it to the "minimum necessary" in wilderness?

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FISH AND WILDLIFE SERVICE WILDERNESS RESEARCH NEEDS

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Basically, the Fish and Wildlife Service has two distinctly different types of areas that have been designated as wilderness. They are (1) true wilderness or areas that fit everyone's description of what wilderness should be or is, for example, in Alaska and some larger areas in the lower 48 States, and (2) lands that simply have a wilderness designation and really don't fit the true wilderness concept. These areas are small (many less than 5,000 acres) and do not possess true wilderness qualities, as they have definitely been trammeled by man.

The problems of managing these wilderness areas, as well as the research needs, are quite different for each area, depending on where it is located. In the lower 48, the problems are mainly from outside influences, such as adjacent land uses, as many areas are reverted farmland that was once in private ownership, very flat, and only distinguished from adjacent land by a fence or a road.

From within many of our wilderness areas, one can see farmers working in their farm fields, towns, farm headquarters, highways and associated traffic, and powerlines, therefore detracting from what visitors gain from other wilderness experiences.

MANAGEMENT PROBLEMS

Because of the close proximity of adjacent privately owned lands, we have experienced problems with noxious weeds which of course are in violation of local weed district regulations, vehicle trespass, and a host of other problems. There is also a problem with water quality or runoff from adjacent land. Some of the problems with management and grazing of livestock have been inherited with wilderness designation, and require fences and watering facilities to maintain. Of course, they require vehicle access. Fire is also an important management tool, and of course there is the problem with smoke. We also have some areas with outstanding mineral rights, and the third party has the right of ingress and egress to gain access to mineral development.

Many of these problems can and have already been solved by our agency through management and education of the public. These problems do not, and will not, require research projects to solve.

Even though many of the areas are not true wilderness, the Fish and Wildlife Service is grateful for the added protection afforded to the land by the wilderness designation.

For our true wildernesses the problems and research needs take on a different twist. In Alaska, most of the State is wilderness, small "w," and therefore areas designated as wilderness tend not to be appreciated by many users or visitors. In some areas, too many visitors are competing for the resources that are available, and most are located in very fragile areas. The use of motorized equipment has been built into the establishing legislation of some areas, thereby permitting the use of boats, snow machines, and airplanes. No mention of horsepower size was made; therefore, because of the fragile soils and tundra vegetation, some problems with camping, access points, and trail heads are occurring and more are anticipated. We are undoubtedly going to need assistance to determine the effect of such uses on these areas. This is true for all lands, not just wilderness.

There is a general lack of a code of ethics, and many Alaskans are not sensitive to what they have, as many still have a frontier philosophy. It might also be noted that whenever added restrictions on the land are imposed, the administering agency must have capability of enforcement or the whole thing becomes a farce.

SCIENCE CAN HELP

The scientific community can help by being aware of the problems and issues and assisting with solutions. As Dick Smith pointed out earlier in the conference, all the research in the world will not solve problems unless there is an acceptance by the public to make changes in land use or recreation use. Many solutions will end up in a political arena, and input or assistance from a number of people or organizations will be needed.

In summary, wilderness problems or problems in wilderness must be elevated as high priorities of agencies, then dollars will be made available for solution. We have heard many problems and research needs discussed here today, but all the data or information obtained are not worth a hill of beans if agencies do not use them to implement changes. We also have heard the old excuse by some agency people that they cannot do something because of a lack of funds. If priorities are high enough in any organization, they can usually find a way to get them funded.

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SIX CATEGORIES OF NEEDED WILDERNESS RESEARCH

Joyce M. Kelly

Before I begin my remarks I would like to take the opportunity to thank the research community for the assistance and advice it gave freely to the Bureau of Land Management while I was there as Chief of the Wilderness and Recreation Program.

Over the past few days we have heard what's happening in the wilderness research arena and what additional needs exist. I would simply like to highlight a few areas that I believe need special attention.

LIMITS OF ACCEPTABLE CHANGE

Each State office (BLM) or region (Forest Service) should be encouraged to do a Limits of Acceptable Change (LAC) pilot project for at least one wilderness to demonstrate the effectiveness and utility of the concept. This would facilitate setting management guidelines for other wildernesses in the State or Region and would aid in setting thresholds for where and what kind of action was required.

The concern I am expressing here is that if there is only a single pilot project, or several, then the likelihood of adaptability by other States or Regions is limited simply because the strategy may not translate. Thus, the concept may be prematurely rejected simply because the geography and site are so different. For example, a LAC model in Aravaipa Canyon, AZ, has limited applicability to Bear Trap Canyon, MT.

COST OF MANAGEMENT

Unless assessments are available as to what it costs to manage an area, there will be little real incentive to look at more cost-effective management strategies. Studies of cost-effective management schemes and strategies would be a major step forward in helping eliminate administrative limitations and those restrictions that may be inherent in the law.

Basically, this is a data problem where there has been little detailed site management information available. It's also an area where the Federal agencies are often reluctant to have others investigate. An analysis we did of a wilderness management contract in Eagle Cap Wilderness suggested some real opportunities for cost savings to the Forest Service. While there was a concern over expanding this concept because an agency may not always find an appropriately committed contractor, I believe it is important to investigate these opportunities to determine their constraints and possible applicability on a wider scale.

IMPACT OF FEES

We are all aware of the growing concern and discussion about the need to increase user fees. This has been a major push by the Administration, which is not surprising in light of the growing Federal deficit.

The question I would like to put on the table is: How much revenue can an area be expected to generate? And more important, should it be expected to generate a certain level? Should we be viewing wildernesses or recreation areas as true revenue generators? Are these areas truly capable of providing a net revenue source to the U.S. Treasury once you assess the costs of implementation, and administrative overhead?

Or are user fees really a management tool to control and direct use, an offset to management costs, a way of averting more decline in recreation budgets, a way of communicating with the public that these areas need financial assistance? I don't think it has been clear what the objectives of user fees, excise taxes on equipment, and other charges are. Some clear analysis is needed before policies are developed in this area that create expectations that can never be fulfilled.

LAW ENFORCEMENT ISSUES

As a first step in resolving law enforcement issues, we need to define what legal research is needed on what issues. What is the nature of the violations, how successful are the prosecutions, what are the constraints to more successful prosecution?

In wildernesses, enforcement is limited to patrol by plane or by foot or horseback. This obviously imposes practical limitations. The tools of the enforcer are restricted, yet the tools of the violator are not. Are there management tools available that we haven't explored? Considering this area raises questions of whether unique resources which need special protection, for example, endangered species, archeological resources, paleontological resources, should be included in wildernesses. This is an issue that is often raised in debates on wilderness allocation and one that needs to be addressed.

How can civil penalties be made more effective and used for their deterrent value? Civil penalties are considered more desirable by the Government because the Government needs only to prove a "preponderance of evidence" versus "beyond reasonable doubt"—the criminal case requirement. In the latter case, the accused has more "outs" and generally will end up with nothing more than a misdemeanor.

Another problem in the legal arena is how to evaluate damages. The Federal Land Policy Management Act provides for fines up to $2,000 and up to a year in jail; it requires nothing in terms of rehabilitating the resource. We often lack the most rudimentary information necessary to value the resource that has been damaged. Another question here is who makes the value determination? Should the violator participate in setting the value of the resource damaged?

Which enforcement penalties work and which ones don't? What do we know about our successes and failures? Are there discentives which could be created through the legal system? Are there tools which could be used and aren't?

FAILURE—CAN WE LEARN FROM IT?

All too often failure or lack of success in research and management is seen as information we should bury, when we should be viewing it as contributing to our knowledge and understanding and treating it accordingly. Failure should be seen as an instructive learning device and shared. Instead we tend to hide results when they don't verify or validate our expected results.

Rather, failure should be seen as a source of knowledge that can help. To fear revealing unexpected outcomes only stifles creativity and experimentation, and causes needless repetition by others. We need to share our incomplete successes or failures as well as our successes.

BLM LANDS—A NEGLECTED RESOURCE

Not surprisingly, the focus of the wilderness allocation effort and the wilderness management effort has been on protecting wilderness that has trees and trails.

We saw from the presentations yesterday that one of the great remaining wilderness areas in this country is in the Great Basin—in many of the areas managed by the BLM. We were also told these are the areas where there is the greatest paucity of information.

The BLM lands represent a unique resource, which may in fact be much more fragile than the forest, with longer term impacts and more difficult reclamation. These lands have different use patterns due in part to lack of control of access. Therefore, they also have different management needs and different resource protection needs. Most research done which is applicable to these areas deals with off-road vehicle problems and impacts. A critical management question is how to direct the user away from a sensitive resource where there are no trails, no control over access, and no physical barriers.

What this means is that we need to assess what constitutes primitive desert recreation, its use, the impact of use, indicators of overuse, and distribution of use. These resources need attention from the research community as well as from the public. The research community can help raise the consciousness of the public to these issues as well.

Now the final challenge. 1991 is fast approaching—the year that signals the close of the BLM wilderness study process. That leaves very little time for basic research into use patterns on those last remaining "wildlands" identified by Rod Nash yesterday. But there is ample time and opportunity for us to test the thesis that these remaining wildlands can be brought into the wilderness system because of their esthetic, psychological, humanistic, and cultural values.

The challenge is to you, Rod, and others who believe strongly that these are the correct arguments, to enter into the wilderness debate now occurring in the deserts of California, the Great Basin of Idaho and Nevada, the canyons of Utah, and the deserts of New Mexico. The BLM wilderness coordinators on the front lines need articulate spokesmen now, as the boundaries of the study areas are being whittled away.

History is written in the present. I don't want to read in the next edition of **Wilderness and the American Mind** that these desert wildlands were lost because the wrong arguments—recreation, economics, scenery, and the future—were made by the bureaucrats. I want to read how you, Rod, and others helped win the battle and prove the merits of these historical values.

The ball is in your court. Will you accept the challenge?

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NATIONAL WILDERNESS RESEARCH CONFERENCE HIGHLIGHTS

Paul C. Pritchard

I am honored and challenged to be given the task of summarizing this conference. To do this, I will divide my comments in three sections. First, I would like to talk about what I think wilderness research is. Second, I would like to talk about what I think the needs are for research based upon your comments. And third, I'd like to talk about the experience of the conference itself.

"What is wilderness research?" That, of course, is comprised of two questions. The first question is "What is research?" From my perspective, and as my good friend Lynn Greenwalt summarized, research is giving meaningful thought to an issue. In this case, the critical term to you as professionals and to you as managers is "meaningful" from a personal fulfillment standpoint—to you as professionals, you as managers—but it must also be meaningful from a social value standpoint.

"What is wilderness?" It is, in fact, a social issue, a social movement; and, therefore, we cannot separate those two definitions nor should we try to do so. Nash pointed out that we would be negligent if we tried to talk about the sciences separated from the humanities and arts. All sections of our society relate to and we hope benefit in varying degrees from research. Lucas went back to the 1880's and talked about research and history moving up to Leopold, the ORRC Commission, the Park Service, the Fish and Wildlife Service, and, of course, the Forest Service's fine job. He talked about what research is as it relates to wilderness. Roy Feuchter pointed out that wilderness comprises areas of great magnitude. For example, 112 of the 122 units of the National Forest System have wilderness in them, and these will grow in number and size. Driver talked about seven benefits. I won't summarize those, but I thought it was interesting that he moved all the way from the concept of knowledge for knowledge sake, to the whole concept of optimizing management.

DEFINITION STILL NEEDED

But in this "age of chips, chips, and chips," of computer chips, of wood chips, and fish and chips, it seems to me what we really need to deal with is the question of the definition of wilderness. We really have only begun to address the issue as I think we probably should. Before the meeting I asked a friend of mine, who as a Biblical scholar has been looking at cultural references we have to "wilderness," to give me some idea of what wilderness is from that perspective. He wrote me a note and I would like to share a few of his comments at this time. He said, "The city represents a world created by us humans—where we seem to be pretty much in charge of things—where things are more or less predictable, orderly, traditional, rational. In wilderness, life is not rational or ordered in the traditional way of thinking. It is the realm of the imagination, of intuition, of symbols. In the wilderness the people of Israel learned to trust God for their survival and to live one day at a time without knowing what the next day would bring. Our lives today are not far from the days of the Old Testament with political upheavals, social unrest, and the potential of nuclear war." He went on to say, "Most of our people spend most of their time living in the city. But periodically the wilderness invades their lives in the form of some crisis or transformation where they discover afresh that we really are not in control." In conclusion he said, "We can only be helpful to people in those wilderness times if we learn to be at home in the wilderness."

People like Thoreau and Emerson have been saying to us that the wilderness represents a great opportunity for us. And that's what I think we are looking at in this conference. We need to step back and realize that we are, in fact, dealing with a much broader social issue—something out of our heritage, our culture, going back not only to Europe but to the very foundation of the Judeo-Christian ethic.

NEEDS HIGHLIGHTS

The second point is what are the needs in research. I thought the panel did an excellent job of summarizing the needs, but let me see if I can highlight just a few points that I thought were important. In talking about six research needs, McCool mentioned the need to look at the effectiveness of tools. That is something that we are very concerned about at the National Parks and Conservation Association (NPCA) because we base our legislative work on good science. We pride ourselves on being accurate; therefore, we depend on you to conduct research to give us accurate information which will have standing before Congress. McCool also mentioned the need for management of biophysical impacts and consequences of use. The conflicts aspect was brought up by Schreyer, Stankey, and Nash. Schreyer mentioned the four most common motives of visitors to wilderness areas—to have social interaction, to experience nature, to escape from our world, and to experience solitude. Nash

noted those core defenses are weak, that is to say wilderness is important in order to protect scenic beauty, for economic reasons, for recreation benefits, for water/air quality, or protecting the wilderness for future generations. We have also heard about the need to be careful of how we phrase ourselves (be we managers, researchers, or advocates) when we are talking about research. Both Mott and Bob Howard emphasized the importance of gene pools and the lack of attention that we seem to be giving to this very important worldwide issue. Harold Eidsvik brought up a very enlightening point on how the philosophy of wilderness seems to be getting worldwide acceptance, but the tools and the management schemes are not. And I think that is an important challenge for us if we want to work at the international level.

While addressing the needs for research, Davis talked about three very important points. He said we need to have a better definition of variables, we need to have more focus, and we need to have tighter designs. In the Visitors Impact Management Study (carrying capacity study) that we are working on at NPCA, his points definitely apply as we put together that synthesis document.

All of this brings us back to the point: we really don't have a philosophy of wilderness and it's something those of us in the advocacy realm should take on seriously. But advocacy depends on good science and therefore on good research. And it begins to take shape at meetings like this as we thrash out the important role of research itself. We need to develop a clear attitude, a commitment, and a philosophy (as Kilgore and others pointed out) toward such critical issues as fire management, the emergency use of vehicles, the grazing issues, and the allowable uses of wilderness about which BLM Director Burford talked. However, we also need to develop baseline data and the indicators that are so crucial to good science, good research, and good management.

AN IMPRESSIVE EXPERIENCE

Well, that brings me to my third and final point. I would summarize the experience of the conference by saying how impressive it has been to be here for some 40 hours listening to 56 speakers, interacting with 400 participants, and hearing innumerable and invaluable comments. It's been exciting and stimulating to share this experience with representatives from Taiwan, Scotland, Canada, the United States, and elsewhere, with advocates from the Sierra Club, from the National Wildlife Federation, and other fine groups. Something has been missing, though. We haven't had the young and the old; we haven't had the traditional minorities; we haven't had the new emerging minorities. Those are groups we need to think about because they need to hear their concerns voiced as well in meetings like this. But the interaction has been invaluable and is irreplaceable in terms of the discovery of new knowledge and the social interaction of meeting new friends and people that we have known of or heard about but have not had a chance to work with.

A very positive result of the conference has been the formation of the Wilderness Research Foundation. I would like to share two objectives that I heard at the board meeting the other night. One is the realization that wilderness and the other aspects of our society—our art, our culture—are all inextricably interrelated. We must deal with that, accept that, and seek ways of bringing about that wonderful opportunity such as through wilderness art. But more important, a very strong commitment was made to begin the process of building support, testimony, and in other ways to get the budgets for research increased in the Federal agencies. That challenge will be a very important outgrowth of this particular conference and for the Wilderness Research Foundation.

ALL ARE ADVOCATES

I think it's critical that we realize we can't wait for Washington—that we are all advocates in some way. All of us are advocates for the importance of qualitative research that only you as managers and researchers can bring about. It's crucial that we realize that. You are, in fact, advocates like I am at NPCA. You must consider yourself advocates because without that advocacy role we lose the genius and the commitment that was shown by those people that I mentioned earlier. The people—like Marshall, Olmstead, Thoreau, and others—who blazed this trail before us. It is essential we understand that we are not just at the beginning of a realization, but that it has been evolving for generations. Everything is connected to everything else; in wilderness is the preservation of the universe, of the world, of life, and of our very existence. It seems to me that is what we are really talking about. That is the perspective with which we have to go away from here.

On behalf of the coordinators, the sponsors, and all the people here, I leave the thought that you will go forward and live a happy and fruitful life in wilderness.

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Lucas, Robert C., compiler. 1987. Proceedings—national wilderness research conference: issues, state-of-knowledge, future directions; 1985 July 23-26; Fort Collins, CO. Gen. Tech. Rep. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 369 p.

Includes 35 reports giving perspectives on wilderness values, management, and research; states-of-knowledge for wilderness resource research; states-of-knowledge for wilderness user research; and future directions for wilderness research.

KEYWORDS: wilderness values, wilderness management, role of fire, air quality, soil and vegetation, fish and wildlife, water resources, wilderness use

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